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Geology of a Portion of the Everett 15-minute Quadrangle, Bedford County, Pennsylvania

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Geology of a Portion of the Everett 15-minute Quadrangle, Bedford County, Pennsylvania

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by Raymond R. Knowles
Cooperating Geologist
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PLATE 1. Geologic map and cross sections ..... *in pocket*

GEOLOGY OF A PORTION OF THE EVERETT 15-MINUTE QUADRANGLE, BEDFORD COUNTY, PENNSYLVANIA

By

Raymond R. Knowles

ABSTRACT

Folded and faulted Paleozoic sedimentary rocks of the Appalachian Mountain section of the Valley and Ridge province were mapped in the Everett quadrangle of south-central Pennsylvania. These rocks range in age from Upper Cambrian to Middle Devonian and have a total thickness of approximately 12,500 feet. Petrographic studies of the dolomites of the Upper Cambrian Warrior and Gatesburg Formations support the conclusions that dolomitization of these units took place after the sediment was deposited and that dolomitization was a selective process, largely limited to those carbonate rocks which contained clastic or detrital grains.

The principal structures in the mapped area are the Friends Cove and Warrior Ridge anticlines and the Yellow Creek syncline. The cores of both the Friends Cove and Warrior Ridge anticlines are disrupted by major, east-dipping high-angle faults that have thrust the anticlines westward toward the adjacent synclines.

The regional structural interpretation of the mapped area suggests that low-angle overthrust faulting and its associated phenomena produced the existing folded and faulted structures. Where bedding plane thrusts in the Lower Cambrian Waynesboro Formation sheared diagonally upward across the Cambro-Ordovician carbonate sequence to the Reedsville Formation, anticlines were formed. This interpretation is supported by the record of the Kerr-McGee No. 1 Martin well drilled on the Hyndman anticline, just southwest of the mapped area, which encountered a major repetition of the Cambro-Ordovician carbonates. The Hyndman and Friends Cove anticlines are interpreted to have similar origins. The structural relief on the Friends Cove anticline is on the order of 10,000 feet, and on the Hyndman anticline on the order of 6,000 feet. It is probable that these two anticlines represent westward displacement of about three miles of an allocthonous block above the Waynesboro-Reedsville thrust plane.

In south-central Pennsylvania, the Precambrian basement is interpreted to be significantly and broadly warped to correspond to the large regional structures such as the Allegheny structural front, the Nittany arch and the Broadtop syncline, but is not deformed concordantly with the folds of the overlying Paleozoic rocks.

INTRODUCTION

The report is based upon a geologic investigation of a portion of the folded Appalachian Mountains of south-central Pennsylvania. The purpose of the investigation was to map the stratigraphic units in detail and to genetically interpret the geologic structures in the area.

LOCATION AND TOPOGRAPHY

The area investigated is located within the Everett 15-minute quadrangle, in the northeastern corner of Bedford County, Pennsylvania (Figure 1). The mapped area is a diagonal strip trending northeast-southwest across the quadrangle (Plate 1). The boroughs of Bedford, Everett, and Saxton are located near the southwestern, southeastern, and northeastern corners, respectively, of the map area. The total mapped area is about 100 square miles.

The map area lies entirely with the nonglaciated Ridge and Valley section of the Appalachian Valley province (Figure 1). The section is characterized by northeastward-trending, long, narrow ridges separated by valley lowlands. The ridges are heavily wooded and stand 1200 to 1600 feet above the cleared and cultivated valleys.

The maximum elevation in the map area is 2541 feet and the total relief is about 1600 feet. The average elevation of the ridge tops is about 2100 feet and that of the valley lowlands about 1100 feet.

PREVIOUS WORK

The first geologist to visit the map area was H. D. Rodgers (1858), Director of the First Pennsylvania Geological Survey. He described the Friends Cove anticline as a broad, double-crested flexure, having a thrust fault on its western flank.

J. J. Stevenson (1882) studied the area while preparing a report on the geology of Bedford and Fulton Counties. Stevenson concurred with Rodgers' findings. In addition, he recognized faulting in the gap at Everett, and in the vicinity of Henrietta, just north of the map area, correctly inferred the presence of the East and West Henrietta faults.

Subsequent geologic investigations in the Bedford-Everett-Saxton area have been limited to reconnaissance studies as part of the work leading to publication of state geologic maps. The area has not been previously mapped in detail.

Butts (1945), as part of his regional study, mapped the Hollidaysburg and Huntingdon quadrangles, directly north and northeast of the present area of investigation.

Above seven miles southwest of Bedford, the Kerr-McGee Petroleum Company drilled an exploratory well (No. 1 Martin) on the Hyndman anticline (see Figure 17). In this report, the data from this well (1963 Guidebook, Pittsburgh Geological Society) are used to interpret the structure of the Hyndman anticline and, by analogy, the structure of the Friends Cove anticline.

The systematic investigation of the regional stratigraphy of south-central Pennsylvania began with the work of Ulrich (1911) and Butts

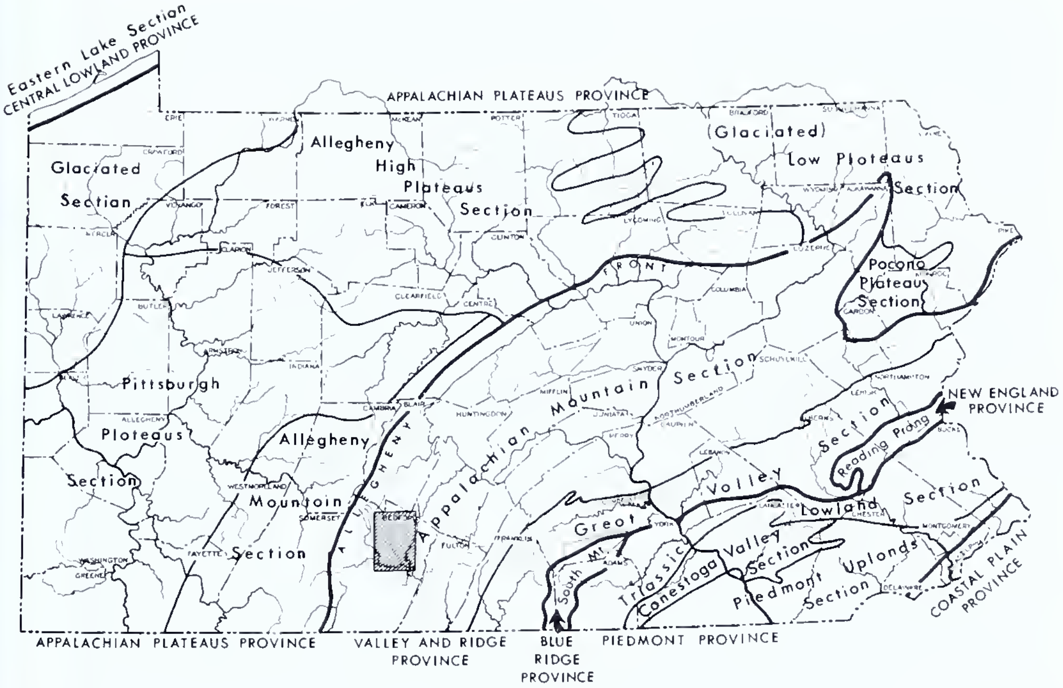

Figure 1. Physiographic subdivisions of Pennsylvania showing location of the Everett quadrangle.

(1918) and has continued to the present day. Where applicable, reference is made to these investigations in the section on stratigraphy in this report.

PRESENT INVESTIGATION

The present investigation included geologic mapping and laboratory studies. Field work was conducted during the summers of 1961, 1962, and 1963. The geology was mapped directly on aerial photographs at a scale of 1 : 20,000 and then was transferred to the Everett topographic quadrangle. This quadrangle (surveyed in 1900) contains errors in topography so that locally geologic contacts mapped during the present study do not follow the map topography.

The geologic cross sections were drawn on the assumption of concentric folding, except where field mapping indicated that the folding is disharmonic.

Depending upon the amount of exposure, stratigraphic sections were measured either by direct measurement with a yard stick or by pace and compass method.

Specimens were collected for later paleontologic and petrographic studies in the laboratory. The results of the paleontologic studies were used to identify and determine the age of the strata. In the petrographic study of the detrital rocks on the map area the writer has used the classification of sedimentary rocks proposed by Krynine (1948). The petrographic investigation consisted of a detailed study and description of selected thin sections.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to several people who aided in the completion of this investigation. Appreciation is extended to Dr. Lawrence H. Lattman for his excellent suggestions and encouragement during all phases of this investigation. Appreciation is also extended to Dr. Carlyle Gray, formerly of the Pennsylvania Geological Survey, for suggesting the problem. I wish to thank Drs. Donald Hoskins and Vinton Gwinn for visits to the map area while field work was in progress.

The writer gratefully acknowledges the financial support of the laboratory phase of the study by the Department of Geology of the Pennsylvania State University.

Finally, I wish to thank the Pennsylvania Geological Survey and Dr. Arthur A. Socolow, Director, whose encouragement and financial support made this study possible.

ADDITIONAL WORK

The report was edited by Dr. Donald Hoskins of the Pennsylvania Geological Survey. The trace of the East and West Henrietta faults and their surrounding hills, and short portions of the contacts of the lower and middle Silurian formations south and west of the south end of Warrior Ridge were remapped by Dr. Hoskins during the spring of 1965. The fault east of Foreman offsetting Tussey Mountain and the trace of the fault offsetting the Bald Eagle Formation east to Bedford also were mapped at this time. The section of Structural Geology was revised and rewritten to incorporate these new data. The portion of the section on Stratigraphy dealing with the Keyser and Old Port Formations was rewritten by Dr. Hoskins based on his additional field work in the Everett quadrangle.

STRATIGRAPHY

Only sedimentary rocks are exposed in the map area. They range in age from Upper Cambrian to Middle Devonian and have a total thickness of approximately 12,500 feet (Figure 2).

The Cambro-Ordovician rocks consist of a thick body of marine limestones and dolomites which grade upward into a continental clastic sequence of shale and low rank graywacke in the Upper Ordovician. The Lower Silurian rocks consist of orthoquartzites which grade upward into shales and limestones in the Middle and Upper Silurian. Lower Devonian rocks also consist of limestone. A thin orthoquartzite

SYSTEM	SERIES	ROCK UNIT		THICKNESS	LITHOLOGIC DESCRIPTION
		Recent stream deposits			Unconsolidated sediments
Devonian	Middle	Mahantango Formation		1075′	Dark- and olive-gray shale and silty shale with some sandstone.
		Marcellus Formation		217′	Black, carbonaceous, paper-thin, fissile shale.
		Onondaga Formation		77′	Dark- and greenish-gray calcareous shale. Some limestone at top.
	Lower	Old Port Formation	Ridgeley Sandstone Member	111′ to 122′	Whitish- to tannish-gray orthoquartzite with a calcareous or siliceous cement.
			Shriver Member	100′	Dark-gray, noncalcareous ,siliceous (cherty) shale and silitstone.
			"New Scotland and Coeymans" Members	80′	Nodular and medium-bedded bioclastic limestone with chert; contains masses of *Favosites* and *Stromatopora*.
Silurian	Upper	Keyser Formation	Upper part	93′	Thin-bedded, laminated limestone; upper part bioclastic.
			Middle part	20′	Cherty and arenaceous limestone.
			Lower part	87′	Nodular limestone.
		Tonoloway Formation		460′	Dark-gray, thin bedded, laminated limestone with some medium-bedded nonlaminated layers.
		Wills Creek Formation		480′	Pale-olive- and greenish-gray, calcareous shale. Dark-gray shale and limestone interbeds. Some sandstone at top.
		Bloomsburg Formation		41′ to 65′	Grayish-red shale with thick beds of siltstone at base and middle.
		Mifflintown Formation	Upper McKenzie Member	70′	Pale-olive, greenish-gray and dark-yellowish-brown shale with interbeds of dark-gray calcareous shale and limestone.
			Rabble Run Member	88′	Grayish-red shale.
			Lower McKenzie and Rochester Members	270′	Similar to upper McKenzie Member.
			Keefer Sandstone Member	3 to 10′	Dark-gray, calcareous sandstone and whitish siliceous sandstone.
	Middle	Rose Hill Formation		575′	Interbedded olive-, greenish-, brownish- and reddish-gray shales and siltstone with some sandstone.
	Lower	Tuscarora Formation		525′	Hard, massive, siliceous orthoquartzite, often laminated and cross-bedded.
Ordovician	Upper	Juniata Formation	Upper member	175′	Reddish- and pinkish-gray protoquartzite and orthoquartzite.
			Middle member	427′	Interbedded reddish-gray shale and sandstone in ratio of about 4:6.
			Lower member	426′	Reddish-gray alternating sandstone and shale in ratio of about 9:1.
		Bald Eagle Formation	Upper member	290′	Light-olive-, brownish- and greenish-gray, low-rank graywacke.
			Lower member	242′	Interbedded light-olive-, brownish- and greenish-gray shale and sandstone.
		Reedsville Formation		1310′	Dark-gray, greenish-gray, and olive-gray shale and siltstone with thin sandstone layers. Thick dark-gray sandstone at top.
	Middle	Coburn Formation		>50′	Dark-gray, laminated and cross-bedded, fine-grained limestone.
		Salona Formation		160′	Dark-gray, thin-bedded, partly argillaceous limestone. Several thin bentonites.
		Nealmont Formation		86′	Dark-gray, thin-bedded, crinoidal and laminated limestones.
		Benner Formation		87′	Medium-gray, partly laminated limestone upper third: crinoidal and massive limestone lower two thirds.
		Hatter Formation		61′	Dark-gray, massive limestone and banded limestone.
		Loysburg Formation		~146′	Interbedded laminated and nonlaminated limestone above; banded limestones and dolomites below.
	Lower	Bellefonte Formation		~1000′	Medium-gray, pure to argillaceous dolomite, partly laminated and oolitic. Cherty near base. May include dolomitic facies of Axemann at base.
		Nittany Formation		~1000′	Alternating dark-gray and medium-gray, mottled, laminated and structureless dolomite. White oolitic chert.
		Larke Formation		~200′	Laminated, oolitic and calcareous dolomite with some intraformational conglomerates.
Cambrian	Upper	Mines Formation		~200′	Medium- and dark-gray, crystalline dolomite. Black oolitic chert.
		Gatesburg Formation	Upper sandy member	642′	Orthoquartzite and dolomitic sandstone interbedded with pure to argillaceous dolomite in ratio of 1:10.
			Ore Hill Limestone Member	147′	Finely crystalline limestone and interbedded dolomite.
			Lower sandy member	616′	Similar to upper sandy member
			Stacy Dolomite Member	68′	Dark-gray, alternating structureless, cryptozoon and oolitic, crystalline dolomite.
		Warrior Formation		—	Dark-gray, thin-bedded limestone, algal and oolitic limestone. Partly dolomitic. Some orthoquartzite and dolomitic sandstone.

Figure 2. Summary stratigraphic column.

occurs at the top of the Lower Devonian. The Middle Devonian rocks consist of marine shales and thin sandstones.

The formations in the Everett quadrangle area have been mapped largely on the basis of lithologic criteria and topographic expression. Some formations and members were combined into a single mapping unit where they were too thin or too poorly exposed to be mapped separately. The Middle Ordovician limestones have been combined into two mapping units using the terminology and subdivisions proposed by Kay (1944). The Upper Silurian Mifflintown Formation (Miller and Conlin, 1961) includes the Keefer, Rochester, and McKenzie Members. These three units have been combined into a single mapping unit because the Rochester cannot be distinguished from the McKenzie without the aid of fossils and because the Keefer is too thin to map separately. The Lower Devonian Shriver, New Scotland and Coeymans units are too thin to be mapped separately and are combined with the Ridgeley sandstones to constitute the Old Port Formation in the manner suggested by Conlin and Hoskins (1962) and Dyson (1963).

CAMBRIAN SYSTEM

Warrior Formation

The Warrior Formation (Butts, 1918, p. 528) crops out as a quarter-mile-wide northeastward-trending band along the west side of Snake Spring Valley. The Warrior is not resistant to weathering and consequently forms a low, rolling, grass-covered surface upon which sink holes are frequently developed. The formation is poorly exposed. In Snake Spring Valley, only the upper 500 to 600 feet of the Warrior is present; the lower portion has been cut out by the Friends Cove fault.

The Warrior Formation may be divided into two units, an upper unit of medium- to thin-bedded, dark-gray limestones with some dolomite, and a lower unit containing mostly dolomitic beds, some quartzite layers, and limestone beds similar to those found in the upper unit.

The contact between the Warrior Formation and the overlying Gatesburg Formation is placed at the change from the algal limestone and platy limestone float of the Warrior to the dark-gray, coarsely crystalline dolomites of the lower part of the Gatesburg Formation.

The upper unit of the Warrior Formation is estimated to be 200 feet thick and is largely composed of medium- to thin-bedded, finely crystalline limestone, algal limestone and oolitic limestone. The algal and oolitic limestone accounts for about 15 per cent of the unit. Thin- to medium-bedded limestones occur in one- to four-foot-thick layers of dark-gray, finely crystalline limestone varying from pure to argillaceous. Near the top, middle, and lower portions of the unit are several one- to two-foot-thick layers of dark-gray, finely crystalline, algal limestone. The tops of some of these algal beds are marked by oolitic limestone. Throughout the section there are one- to two-foot-thick layers of dark-gray, oolitic limestones. This upper unit becomes progressively dolomitic toward the base indicating a gradational contact between the upper and lower units.

The lower unit of the Warrior Formation is composed of medium- to dark-gray, fine- to medium-crystalline, pure to argillaceous dolomite, with some limestone. Alternating beds of algal calcareous dolomite, oolitic dolomite, and thin- to medium-bedded, structureless dolomite are interbedded with the dark-gray, finely crystalline limestone. The limestones are thin- to medium-bedded and commonly show lamination and cross-bedding.

Sandstones occur interbedded with dolomite and calcareous dolomite in two zones: one near the top of the lower unit and a second approximately 200 feet below the first. Both zones contain one- to two-foot-thick layers of orthoquartzite and dolomitic sandstone. These weather to produce an abundant sandstone float similar to that found in the overlying Gatesburg. It is necessary to check for algal limestones and platy limestones above and below these intervals to be sure of being in the Warrior Formation.

Several of the Warrior lithotypes were examined in thin section. Most of the rocks of the Warrior Limestone that show evidence of recrystallization, replacement, or dolomitization contain clastic or detrital grains. If the rock contains clastic and nonclastic portions and has been partly dolomitized, it is the clastic portion which is dolomitic. Two thin-section descriptions will illustrate this. The first is of crytozoon columns with a detrital and chemi-clastic matrix. The thin section was treated with a solution of HCL and $K_3Fe(Cn)_6$ to stain the dolomite (Leroy, 1951). The columns are about 3 cm long and 1 cm wide and about 1 cm apart. The cryptozoon structure consists of semi-circles convex upward, stacked vertically to form columns. These semi-circles consist of 1 to 2 mm thick layers of brown-stained, fine-grained (0.01 to 0.02 mm) calcite alternating with 0.25 mm thick layers of sparry calcite. No portion of the algal column has been dolomitized. The material between the columns consists of pellets and a quartz and feldspar silt in a calcilutite matrix. Much of the matrix has been dolomitized. A crude, semi-circular, concave upward layering is preserved in the undolomitized portion. The layering is due to alternating layers of pellets (size mostly 0.15 mm) and calcilutite. The dolomitized portion consists of a mosaic of dolomite rhombs in which undolomitized pellets and small irregular patches of calcilutite occur. Apparently, the presence of the pellets and detrital grains with an associated increase in permeability favored the dolomitization process.

The second thin section is a laminated calcareous dolomite. The laminae are graded layers approximately 1 cm thick. The base of each layer contains an interlocking mosaic of dolomite rhombs with quartz and feldspar silt and calcilutite pellets derived from erosion of the underlying layer. This clastic layer grades upward into calcite-dolomite lutite. The top of each layer is marked by a ragged erosional contact. Recrystallization has been greatest, i.e. dolomite rhombs larger, in the portion containing the clastic grains, although scattered throughout the calcilutite layer are small dolomite rhombs. The added permeability of the clastic-rich layer may have allowed greater circulation of fluids and thus aided recrystallization of the dolomite.

These thin sections illustrate the following:

(1) The dolomitization process was favored by the increased permeability due to the clastic grains; and

(2) In general, the presence of clastic grains favors recrystallization or replacement.

The sandstones of the Warrior Formation are either arkoses or quartzites, both of which are light gray to white in color, with variable amounts of siliceous and dolomitic cement. To determine whether the difference in the composition of the detrital fraction of these sandstones reflects differences in either provenance or topographic relief, thin sections of the orthoquartzite and the arkose were examined and the heavy minerals extracted.

The orthoquartzite consists of rounded to subrounded quartz grains with a few grains of highly kaolinized feldspar, and a silica cement. The approximate composition is quartz, 73%; rock fragments (igneous?), 4%; limonite, 3%; authigenic barite, 2%; feldspar, a few grains; cement, 13%; pore space, 5%. Silica overgrowths occur on all grains. The quartz, ranging in size from coarse to very fine sand (Wentworth scale), shows an undulose extinction and many bubble train inclusions. The limonite occurs mostly as coatings on the walls of the pore spaces.

The arkose is a fine- to very fine-grained sandstone approximately composed of dolomite (45%), quartz (30%), microcline feldspar (16%), igneous rock fragments and heavy minerals (1-2%), and silica cement (7%). The rock is dolomitic arkose. Ghosts of pellets can be seen in the dolomite, suggesting that some of the carbonate was originally introduced into the rock as pellets.

From the orthoquartzite the heavy minerals identified included:

Detrital

Rutile, as dark-red angular fragments
Zircon, as rounded oval, inclusion-poor grains
Tourmaline, as oval rounded, generally inclusion-free grains, some with colorless overgrowths, many varieties, pleochroic,
tannish brown to olive brown

pinkish brown to dark brown
pale green to dark green
reddish brown to black
colorless to pale yellow
zoned pale green to green

Kyanite, as clear and carbon-filled, elongate and subequent, slightly rounded grains
Andalusite, as clear, angular grains;

Authigenic

Anatase, as aggregates of small, angular grains
Barite, as angular, ragged, apple brown to colorless grains
Leucoxene, as white, opaque, spongy grains

From the dolomitic arkose the heavy minerals identified included:

Detrital

Rutile, as dark-reddish-brown angular grains
Zircon, as clear generally inclusion-free, subrounded to rounded grains
Tourmaline, as slightly rounded, pleochroic grains, few varieties, colorless overgrowths
Kyanite, as rounded, clear and carbon-filled grains
Andalusite, as colorless, clear, angular grains
Hornblende (rare), as subrounded, rhombic grains, pleochroic, light yellow green to olive green
Muscovite (rare), as clear, colorless, ragged-edged grains
Hematite (rare), as red, spongy grains;

Authigenic

Anatase, as opaque, dark red, angular grains
Barite, as ragged, brownish grains
Leucoxene, as white, spongy grains.

Both sandstones thus contain essentially the same heavy mineral suites. The heavy mineral suites indicate that the provenance of the orthoquartzite and the arkose is a granitic and metamorphic terrane. The compositional difference between the orthoquartzite and the arkose may therefore be attributed to a difference in topographic relief of the source area. In the case of the dolomitic arkose the source area may have shown a higher relief so that rapid erosion transferred relatively fresh detritus from the source area to the site of deposition.

The present writer found no fossils in the Warrior Formation other than the gymnosolen- and cryptozoon-type algae. Wilson (1952) studied the fauna of the Warrior in central Pennsylvania and assigned the unit to the Upper Cambrian. He correlated the Warrior with the Big Spring Member of the Conococheaque Formation and the uppermost Elbrook Formation of southeastern Pennsylvania.

Gatesburg Formation

The Gatesburg Formation (Butts, 1918, p. 527) crops out in the central portion of Snake Spring Valley and in the small valley south of Henrietta. Butts divided the Gatesburg into four members: the lowermost Stacy Dolomite Member, the lower sandy member, the Ore Hill Limestone Member, and the upper sandy member. Portions of all four members of the Gatesburg can be seen in Snake Spring Valley in good exposures along the Pennsylvania Turnpike, approximately one and a quarter miles east of Bedford Narrows.

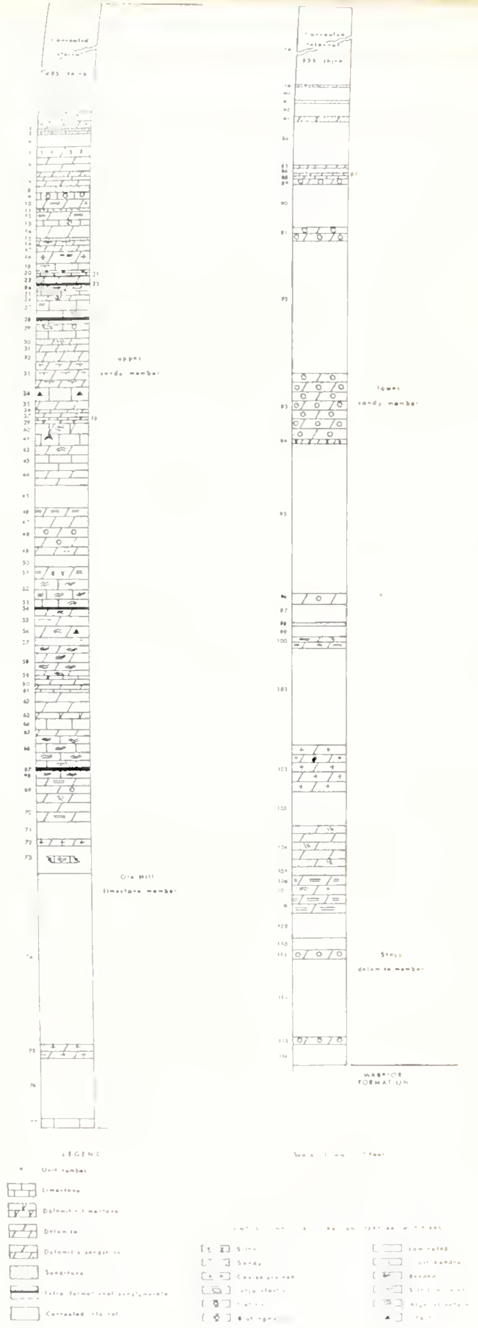

Figure 3. Detailed columnar section of the Gatesburg formation exposed in Pennsylvania Turnpike cut, Snake Spring Valley.

In Snake Spring Valley, the Gatesburg Formation is 1475 feet thick. The following tabulation shows the thickness of the members of the Gatesburg Formation exposed in road cuts along the Pennsylvania Turnpike, Snake Spring Valley.

Gatesburg Formation	
upper sandy member	643 feet
Ore Hill Limestone Member	147 feet
lower sandy member	617 feet
Stacy Dolomite Member	68 feet

The lower contact is drawn at the change in float from the platy limestone of the Warrior to the coarsely crystalline dolomites of the Stacy Member. The upper contact is drawn at the change in float from the sandstones of the upper sandy member to the black oolite cherts of the Mines.

The lowermost or Stacey member consists predominantly of medium-bedded, dark-gray, medium to coarsely crystalline dolomite interstratified with dark-gray, medium-crystalline, cryptozoon dolomite and medium-crystalline oolitic dolomite. There is some thin-bedded, medium-gray, laminated, finely crystalline dolomite.

The upper and lower sandy members are lithologically similar units of interbedded detrital and carbonate rocks in the ratio of 1 to 10. The two members are composed of light-gray orthoquartzite and dolomitic sandstone interstratified with medium- to thin-bedded, dark-gray, medium-crystalline, pure to argillaceous dolomites. The dolomites occur as massive structureless dolomites, as laminated or cross-bedded dolomites, as algal beds of the cryptozoon type, as flat pebble conglomerates, as thin-bedded, light-gray shaly beds, and as oolitic beds.

About 200 feet above the base of the upper sandy member is a 40-foot-thick zone of dark-gray, fine-grained limestone interbedded with dolomite and sandstone. The limestones, which occur in one- to five-foot-thick layers, include massive structureless beds, laminated beds, and oolitic beds.

The Ore Hill Member contains dark-gray, finely crystalline limestones alternating with medium- to dark-gray, medium-crystalline dolomites. The limestones, which make up about 50 per cent of the member, include medium- to thin-bedded, structureless limestones, algal limestones of the cryptozoon type, quartz silt laminated limestone, and one- to three-inch-thick beds of flat pebble conglomerate limestone. Massive structureless dolomites, oolitic dolomites, and platy-weathering laminated dolomites are interbedded with the limestones.

Wilson (1952) measured and partly described the Gatesburg Formation exposed in road cuts along the Pennsylvania Turnpike. The present writer redescribed this section. The section description is presented graphically in Figure 3 and verbally in the Appendix.

Wilson (1952) studied the Gatesburg on a regional level, and Pelto (1942) made a detailed study of a single section near Birmingham, Pennsylvania. Both of these investigators concluded that the Gatesburg Formation is cyclic. Both suggested a similar cyclic sequence. Pelto (1942) presented an ideal or complete cycle for the lower Gatesburg but pointed out that not all the members of the cycle are always present or developed to the same degree.

Pelto's (1942, p. 16) ideal complete lower Gatesburg cycle (Stacey Member) is as follows:

5.	Cryptozoon beds	3″
4B.	Massive black dolomite with oolites, grading downward into	
4A.	Massive black dolomite	1′-3′
3.	Thin-bedded black dolomite	4′-8′
2.	Missing	
1.	Buff dolomite, silty, with a few coarse sand grains, interbedded with thin black dolomite	3″-2′

In addition, Pelto recognized in the middle Gatesburg two variations of this ideal cycle:

Type A

5.	Cryptozoon beds	5″
4B.	Massive black dolomite with oolites grading downward into	
4A.	Massive black dolomite	1′-6′
3.	Missing	
2.	Sandstone	1′-10′
1.	Buff dolomite, lenticular at base of sand	2″-1′

Type B

5.	Missing	
4B.	Missing	
4A.	Missing	
3.	Thin-bedded black dolomite, sometimes highly silty	1′14′
2.	Sandstone	3″-6′
1.	Buff to gray dolomite	3″-6′

In Snake Spring Valley, the Stacey Member of the Gatesburg Formation appears to consist largely of Pelto's Type B cycles, whereas the upper sandy member appears to consist of an interbedding of the Type A, Type B, and Pelto's Stacey Member cycles. Often, the cryptozoon beds at the top of the cycle are missing.

The depositional history of the Gatesburg Formation is easier to understand if the lithotypes which compose it are divided into two classes. The first class includes structureless, thick- and thin-bedded limestones and dolomites, finely laminated limestones and dolomites, banded limestones and dolomites, and argillaceous beds. The second class includes sandstones and sandy dolomites, oolitic and pellet beds, cross-bedded limestones and dolomites, cryptozoon beds (?), silty beds and flat pebble intraformational conglomerates.

When the Gatesburg Formation of the Everett quadrangle area is examined in the light of these two classes, it becomes clear that the formation consists of an interstratification of lithotypes suggestive of deposition in quiet water (Class 1) and lithotypes suggestive of deposition in more agitated water (Class 2). Using this two-fold classification of rock types, two types of cycles are conceived. The first type of cycle begins with the quiet water lithotypes at the base and grades upward into the more agitated water lithotypes, ending with a sharp contact at the top. The second type begins with quiet water lithotypes, and grades upward into the more agitated water lithotypes, and finally grades into lithotypes suggestive of a return to the quiet water condition. Pelto's cycles appear to consist of a combination of parts of two or more of the cycles discussed above.

In thin section, the medium to coarsely (0.1 to 0.3 mm) crystalline dolomites of the Gatesburg Formation are generally pellet or oolitic layers which show evidence of recrystallization and replacement. The finely crystalline dolomites only show evidence of recrystallization and generally occur as finely laminated beds. The limestones are either very fine grained or finely crystalline. The latter in thin section show evidence of recrystallization and replacement.

The Gatesburg Formation contains several nodular band-mottled limestones (units 66, 68, and 52 in section description), in which the mottling consists of irregular dolomitic bands elongate parallel to bedding. Thin-section study of these suggests that the nodular aspect of the mottling results from flowage and injection of the more mobile dolomitic portion into and between the more cohesive calcilutite layers.

The sandstones of the Gatesburg are medium- to fine-grained sands, commonly laminated or cross-bedded, and cemented with either silica or dolomite. The amount of dolomitic cement can be as high as 50 to 60 percent. When it is this high, the ghosts of pellets can be seen in the dolomite indicating that the original sediment was a mixture of detrital grains and carbonate pellets. The sandstones of the Gatesburg are classed as orthoquartzite, protoquartzite, and feldspathic sandstone. The sandstones are largely composed of quartz (68 to 90 percent) and microcline feldspar (0 to 10 percent). The orthoquartzite and the feldspathic sandstone do not contain any chert or rock fragments. The protoquartzite contains quartz, chert, phyllite-schist rock fragments but no feldspar. Where silica and dolomite cement are present in the same sandstone, the silica has preceded the dolomite. The quartz type and rock fragments suggest that the source for these sands was a metamorphic-igneous terrane containing phyllites, schists, and igneous intrusives.

No fossils, other than algae, were found in the Gatesburg Formation. Wilson (1952, p. 291) assigned an Upper Cambrian, Franconian to Trempealeauian age to the Gatesburg Formation. The Gatesburg correlates with the Conococheaque Formation of southeastern Pennsylvania (B. F. Howell and others, 1944).

Mines Formation

The Mines Formation (Butts, 1918, p. 527) crops out in the Snake Spring Valley, and in the small valley south of Henrietta, as a narrow band paralleling the exposure of the Gatesburg Formation. The Mines is not resistant to erosion and consequently forms a low, rolling, grass-covered surface at the general level of the valley floor. The surface is strewn with oolitic chert fragments. The Mines is nowhere sufficiently well exposed to allow a measurement of its thickness. Based on the width of outcrop the calculated thickness is 200 feet. The lower contact was placed at the change from the sandstone float of the Gatesburg to the black oolitic chert fragments of the Mines. The upper contact was placed at the change from the cherty soil of the Mines to the chert-poor soil which marks the Larke dolomite.

The Mines Formation is composed of one- to six-foot-thick beds of massive, medium-gray, medium-crystalline dolomite and dark-gray, coarsely crystalline dolomite interbedded with thinly bedded, dark-gray, fine-grained dolomite. The unit yields large quantities of light-gray, medium-gray, and dark-gray cherts which are dense to vesicular in aspect. Some of the cherts contain small rhombic-shaped cavities. Many of the cherts are oolitic, consisting of small (0.5 to 1.0 mm) black oolites in a lighter gray groundmass. In thin section these siliceous oolites show evidence of having been formed by the silicification of an oolitic limestone.

No fossils were found in the Mines Formation. The only fossil Wilson (1952, p. 291) reports from the Mines is gastropod *Sinuopea* cf. *vera*. In the Conococheaque Formation of southeastern Pennsylvania, Wilson found this gastropod associated with the Upper Cambrian trilobite *Prosaukia* and thus concluded that the Mines may be of Upper Cambrian age.

ORDOVICIAN SYSTEM

Larke Formation

The Larke Formation (Butt, 1918, p. 527) occurs in Snake Spring Valley, and in the small valley south of Henrietta. Portions of the Larke are partially exposed at the south side of the Pennsylvania Turnpike about 400 feet west of the county road leading to Lutztown.

For mapping purposes the Larke Formation is defined as the interval with little chert between the black oolite cherts of the older Mines Formation and the white oolite cherts of the younger Nittany Formation.

The Larke Formation is not resistant to erosion and forms a low, rolling, grass-covered surface. Exposures are poor. The lack of exposures of the Larke and the approximate location of the contacts make the measurement of the Larke's thickness difficult. In Snake Valley, the width of outcrop suggests that the Larke Formation is about 200 feet thick.

Donaldson (1959, p. 61), in a regional study of the Larke Formation, divided the formation into four members. In ascending order they are a lower member of finely crystalline dolomite, a rudite member of cherty nodular beds and finely crystalline dolomite, a middle member of finely crystalline dolomite and an upper oolite member. Units of all four members have been identified in the map area.

The Larke Formation occurs as 1- to 10-foot-thick layers of dark-gray, medium to coarsely crystalline dolomites interstratified with layers of medium-gray, and dark-gray, finely crystalline dolomites. The lower member is composed of medium-bedded (6 to 12 inches), dark-gray, medium-crystalline, cherty dolomites, and thin-bedded, medium-gray, fine-grained dolomites. The rudite member contains thick-bedded, dark-gray, medium to coarsely crystalline dolomites and intraformational conglomerates. The middle member consists of thin-bedded and medium-bedded, dark-gray, fine-grained dolomites. The upper oolite member is composed of medium to coarsely crystalline, medium-bedded (6 to 12 inches), dark-gray layers of pelletic dolomite interstratified with dark-gray, fine-grained dolomites.

Identification of the Larke Formation is based on stratigraphic position and lithology. Material collected by A. R. Spelman and the writer from exposures of the Larke Formation west of Lutztown, Pennsylvania, was identified by E. L. Yochelson of the U.S. National Museum as containing *Gasconadia* and *Pfohileta*. This indicates a Lower Ordovician (Canadian) age for the Larke. Donaldson (1959, pp. 66, 82) on the basis of similar faunal assemblages and similar lithotypes showed that the Larke is a facies equivalent of the Stonehenge Formation.

Nittany Formation

The Nittany Formation (Ulrich, 1911, p. 658) crops out as a continuous northeastward-trending band at the center of Snake Spring Valley. Excellent exposures of the Nittany occur along the Pennsylvania Turnpike just east of Lutztown. A detailed description of this section is included in the regional study of the Nittany Formation by Spelman (1964).

The Nittany forms a low, rolling, grass-covered surface at about the same elevation as the surface developed on the Larke and Bellefonte Formations. In Snake Spring Valley, the Nittany is approximately 1000 feet thick (Spelman, personal communication).

The lower contact was drawn at the change from the chert-poor soil of the Larke Formation to the cherty soil of the lower Nittany Formation. The upper contact was drawn at the change in float from the dark-gray, coarsely crystalline dolomites of the Nittany to the dark-gray, fine-grained dolomites of the Bellefonte Formation.

The Nittany Formation is a cyclic sequence of dark-gray and medium-gray, finely to coarsely crystalline dolomite. Each cycle is from 3 to 10 feet thick, and each cycle contains the following sequence, described from bottom to top:

(1) Laminated dolomite, dark-gray and medium-gray, finely crystalline, 1 to 4 feet;
(2) Structureless massive dolomite, dark-gray and medium-gray, finely to coarsely crystalline, 1 to 2 feet;
(3) Mottled dolomite, dark-gray and medium-gray, medium and coarsely crystalline, 1 to 6 feet.

Unit 2 is not always present.

The laminated dolomite is a thin-bedded to medium-bedded, pure to argillaceous dolomite that often weathers with a ribbed surface. The argillaceous layers weather to chips. The laminae are thin (1 to 3 mm), straight, evenly spaced, alternating layers of lighter and darker colored dolomite.

The mottled dolomite is a medium- to thick-bedded dolomite containing tannish-gray and medium-gray-colored mottling on a darker gray groundmass. The mottles are either irregular, thin, wavy stringers, elongate parallel to the bedding, or small irregular blotches, lacking any orientation. The stringer type mottling imparts a banded aspect to the rock.

On weathering the lower portion of the Nittany Formation yields large quantities of chert. These include dark-gray, dense cherts, often containing rhomb-shaped cavities, cryptozoon cherts, and oolitic cherts containing small white oolites in a dark-gray groundness.

The band mottling and blotchy mottling of the Nittany Formation were studied in thin section. The mottles are areas of either larger or smaller dolomite grains, larger or smaller amounts of inclusions, or larger or smaller amounts of hematite or limonite. When the grain size throughout the thin section was about the same, the mottles and matrix differed in the amount of inclusions and/or hematite or limonite. There seems to be no tendency for the mottles to be dominantly either larger or smaller grained, nor to contain larger or smaller amounts of inclusions or larger or smaller amounts of hematite or limonite. The difference between the mottles and matrix seems to be only a relative difference in one or more of the three properties recognized above.

The primary sedimentary features suggest that the Nittany Dolomite cycle may reflect a subsidence below the zone of wave and current action and a sedimentary upbuilding to the level at which wave and current action begins to rework the sediment, followed by subsidence and a new cycle.

A few *Lecanospira* have been found by A. Spelman (personal communication) in the Nittany Formation south of the study area. On the basis of this gastropod the Nittany is assigned a lower Lower Ordovician Age. The Nittany of south-central Pennsylvania is tentatively correlated with the lower part of the Rockdale Run Formation of Maryland (Sando, 1957, p. 3).

Bellefonte Formation

The Bellefonte Formation (Ulrich, 1911, p. 657) crops out as a continuous band along the eastern and western sides of Snake Spring Valley.

The Bellefonte Formation is slightly more resistant to erosion than the adjacent rocks and often forms a low ridge standing above the valley. A thick chert zone in the lower third of the Bellefonte often marks the crest of this ridge and is an excellent marker bed for mapping purposes. In Snake Spring Valley, the Bellefonte Formation is about 1000 feet thick. The lower 235 feet of this thickness may include the dolomitic facies of the Axemann Formation.

The contact between the Nittany Formation and the Bellefonte Formation is drawn at the last appearance of the dark-gray, coarsely crystalline dolomites of the upper Nittany. The contact between the Bellefonte Formation and the overlying Loysburg Formation is gradational, and has been drawn at the last appearance of the light-gray, fine-grained dolomites typical of the upper Bellefonte.

The Bellefonte Formation is composed of 1- to 20-foot-thick layers of generally laminated, finely crystalline, medium-gray, pure to argillaceous dolomites with interbeds of mottled or oolitic, dark-gray, medium-crystalline dolomite. The layers are generally medium-bedded, although the more argillaceous beds are shaly to thin-bedded and often weather platy. The laminae are either straight, evenly spaced, or slightly curving and discontinuous, and reflect either thin silty layers or color differences in the dolomite. The upper portion of the Bellefonte consists of whitish-weathering, laminated or structureless, light-gray, finely crystalline dolomites and calcareous dolomites. The contact with the overlying Loysburg Formation is gradational, consisting of interbedded limestone, dolomite, and calcareous dolomite.

About 235 feet above the base of the Bellefonte Formation there is a thick cherty zone which on weathering produces blocks up to 3 feet across of dark-gray chert which is vesicular in aspect. Associated with these cherty beds are finely crystalline, and mottled, medium-crystalline, dark-gray dolomites. Chert from the cherty zone was examined in thin section. The chert is a pale-brown-colored mosaic of micro-crystalline quartz in which inclusions of small (up to 0.08 mm) brownish-colored, rhomb-shaped ghosts of carbonate grains may be seen. The chert also contains inclusions of limonite, hematite, air bubbles, and unidentified mineral grains. The presence of carbonate ghosts suggests that the chert beds are a secondary chert formed by the silicification of a carbonate rock.

Butts (1939, p. 18) assigned a Lower Ordovician (Canadian) age to the Bellefonte. Hobson (1958, p. 229) correlates it with the Ontelaunee Formation of southeastern Pennsylvania on the basis of the gastropod *Hormotoma artemesia* being common to both.

Along the Pennsylvania Turnpike, west of Ashcom, at about 225 feet above the base of the Bellefonte Formation (just below the thick cherty zone) the writer found a specimen of the coiled cephalopod *Centrotarphyceras* (?). According to Ulrich and others (1942), this genus is found in the Axemann and basal Bellefonte Formations. The absence of the Axemann as a limestone and the presence of a cephalopod which could be of Axemann age suggest that the lower 235 feet of the Bellefonte in the study area may include a dolomitic facies of the Axemann Formation. Two additional lines of evidence suggest that this may be true. Lees (1964) reports that at the type locality the Axemann is overlain by thick cherty beds which belong to the Bellefonte and that southwest of the type locality the Axemann Formation becomes dolomitic.

Benner, Hatter and Loysburg Formations Undivided

Kay (1944) studied the Middle Ordovician Limestones of central Pennsylvania and defined the formations and members of the Lower Mohawkian and Chazyan Stages. Because of poor exposure in the study area, the formations and members proposed by Kay cannot be mapped with any certainty. The present writer has therefore considered the Benner, Hatter, and Loysburg Formations as a single mapping unit but has indicated in the section description at Ashcom (see Appendix) Kay's subdivisions of these rocks.

In Snake Spring Valley, the Benner, Hatter and Loysburg Formations crop out as a continuous belt along the base of the anticlinal side of Evitts and Tussey Mountains. Excellent exposures are to be found in the New Enterprise quarry at Ashcom and along the Pennsylvania Turnpike south of Ashcom. The Benner, Hatter and Loysburg Formations are not very resistant to erosion and consequently form a low, rolling grass-covered surface at about the same level as the valley.

The following tabulation shows the thickness of the formations and members exposed in the New Enterprise quarry at Ashcom, and along the Pennsylvania Turnpike south of Ashcom. The subdivisions are those proposed by Kay (1944).

Benner Formation		
Stover Member	28.0	
Snyder Member	58.7	
Total		86.7 feet
Hatter Formation		
Hostler Member	60.8	
Total		60.8 feet
Loysburg Formation		
Clover Member	69.0	
"tiger-striped" Member[1]	146.0[2]	
Total		215.0 feet
Total thickness		362.5 feet

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[1] This unit was informally named the Milroy Member by Rones (in Swartz and others, 1955, p. F6).

[2] Inferred from Kay, 1944, p. 6.

The contact with the overlying Nealmont Formation was drawn at the change from the crinoidal limestones of the Benner to the platy-weathering limestones of the Nealmont. The lower contact is gradational; the limestones of the Loysburg Formation are interbedded with the dolomites of the Bellefonte Formation. The contact was drawn at the stratigraphically highest occurrence of the light-gray, fine-grained dolomites distinctive of the upper Bellefonte Formation.

The upper third of the Benner Formation, the Stover Member, is composed of 4- to 6-foot-thick layers of partly laminated, thick-bedded, medium-gray, fine-grained, pure to argillaceous limestone. Toward the base of the Stover Member, the limestones become dark gray and partly crinoidal. The lower two-thirds of the Benner Formation, the Snyder Member, consists of thick-bedded, dark-gray, fine-grained limestone, interlayered with thick-bedded, dark-gray, coarsely crystalline, crinoidal limestone.

Only the Hostler Member of the Hatter Formation is found in Snake Spring Valley. The upper half of the Hostler Member consists of thick-bedded, dark-gray, banded limestones, and the lower half consists of thick-bedded, dark-gray, laminated limestones. Interstratified throughout the Hostler Member are thick-bedded, very fine-grained, grayish-black limestones.

The Loysburg Formation contains two members, the Clover Member and an unnamed member informally called the "tiger-striped" member. The upper or Clover Member is composed of laminated and non-laminated layers of thick-bedded, dark-gray limestone with interbeds of medium-gray and grayish-black, very fine-grained limestone. There are some 1- to 2-inch-thick layers of limestone pebble conglomerate near the base. The "tiger-striped" member is composed of dark-gray, laminated and nonlaminated, medium- to thick-bedded limestones and dolomitic limestones. Interstratified with these beds are banded limestones and silty dolomites.

In the New Enterprise quarry, south of Ashcom, excellent exposures of the Benner, Hatter, and Loysburg Formations are to be found. A detailed description of this section is presented in Figure 4 and in the Appendix.

Thin sections of the clastic, laminated, and banded limestones were studied. Bioclastic limestones from the Snyder Member of the Benner Formation are poorly sorted calcarenites containing recrystallized bioclasts and calcilutite pellets in a calcilutite matrix that has been partially recrystallized to a sparry calcite. The calcilutite matrix contains closely packed, well-formed dolomite rhombs. Thin sections of the clastic limestones of the Hostler Member indicate that they are similar to those of the Snyder Member. They differ only in the amount of bioclasts and the extent of recrystallization of the calcilutite matrix.

In hand specimen, the dark-gray, laminated limestones from the Hostler Member are composed of straight, evenly spaced laminae of alternating lighter gray and darker gray. In thin section the darker colored laminae are composed of very fine-grained calcite. The lighter colored layers are composed of small (0.05 mm), circular to elliptical, calcilutite pellets with authigenic dolomite rhombs occurring in the space between the pellets. Pellet-filled dike-like connections between the pellet layers also contain dolomite rhombs. Apparently, the pellet zones were important in determining the location of the dolomite.

One of the "tiger-striped" beds is composed of 1- to 2-cm-thick bands of alternating medium-gray and light-medium-gray limestone. In thin section the rock is a mixture of calcilutite and euhedral dolomite. The dolomite is sparsely distributed in the medium-gray bands, but it becomes highly concentrated in the light-gray bands.

The Benner, Hatter, and Loysburg Formations of central Pennsylvania are assigned to the lower Middle Ordovician and correlated with the Chambersburg Formation and the Stones River Group of southeastern Pennsylvania (Twenhofel and others, 1954).

Coburn, Salona, and Nealmont Formations Undivided

Because of poor exposure the subdivisions of the Trenton Group (Coburn, Salona, and Nealmont Formation) discussed by Kay (1944) cannot be mapped with any certainty. The writer has mapped the Trenton Group as a single unit.

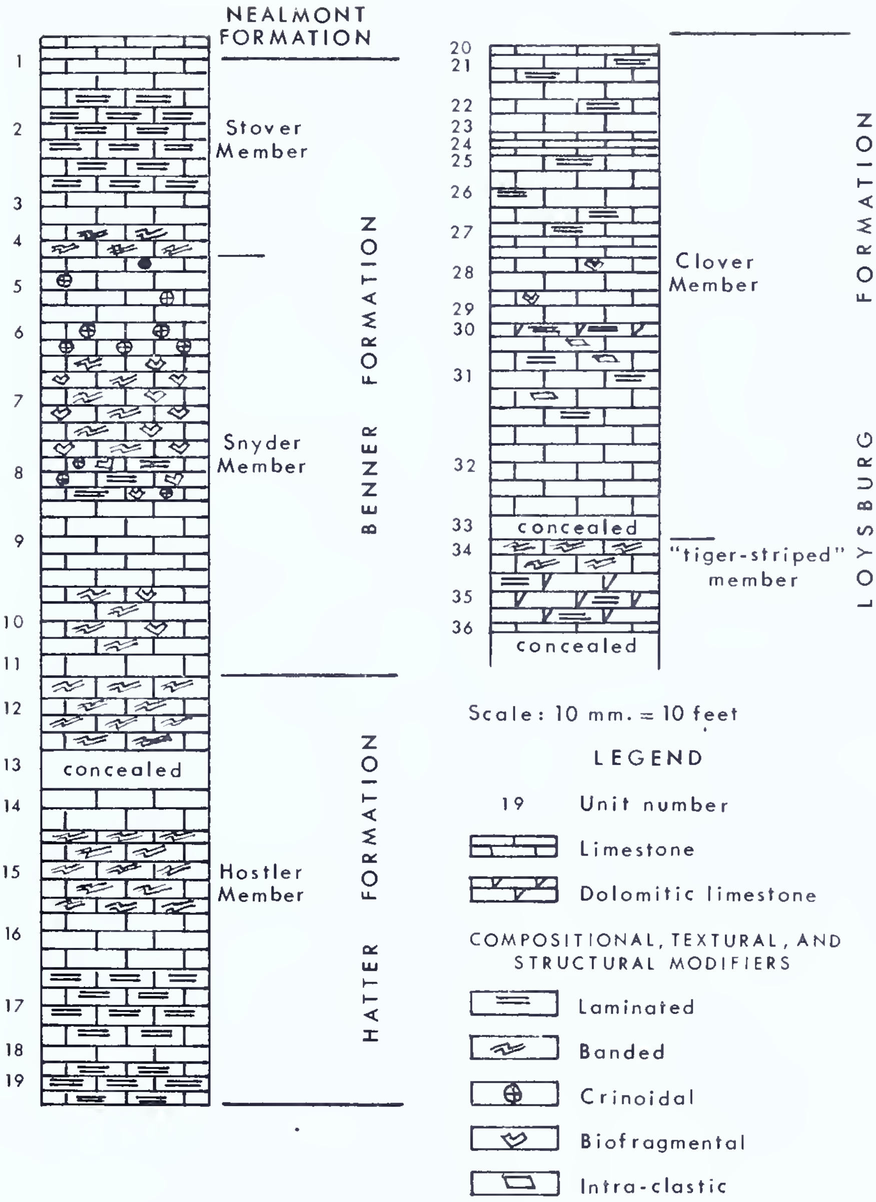

Figure 4. Detailed columnar section of the Benner, Hatter and Loysburg Formations exposed in the New Enterprise quarry at Ashcom.

In Snake Spring Valley, the Trenton Group crops out as a linear belt along the anticlinal side of Evitts and Tussey Mountains. The exposure of the Trenton Group is marked by a low, rolling, grass-covered surface upon which a platy limestone float is common.

In Snake Spring Valley the Trenton Group is about 300 feet thick. The following tabulation shows the thickness of the individual units of the Trenton Group as measured in the New Enterprise quarry at Ashcom. The subdivisions are those proposed by Kay (1944).

Trenton		
Coburn Formation		50.0 feet*
Salona Formation		160.0 feet*
Nealmont Formation		
Rodman Member	38.7	
Centre Hall Member	31.1	
Oak Hall Member	26.3	86.0 feet
Total thickness		296.0 feet

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* From Thompson, 1961, p. 253.

The upper contact was drawn at the change from the platy limestone float of the Trenton Group to the shale-chip soil of the Reedsville Formation. The lower contact was drawn at the first appearance of coarsely crystalline, crinoidal limestone below the platy limestones of the Trenton.

The Trenton Group is composed of thin-bedded (½ to 1 inch) and thicker bedded (1 to 6 inches), dark-gray to very dark-gray, fine-grained limestones. Interstratified with these beds are dark-gray, biofragmental limestones and thin (1 to 2 inches) layers of dark-gray, argillaceous limestones. The Nealmont is thicker bedded and contains many bioclastic beds. The Salona contains several thin, yellowish-brown-weathering bentonite layers. The contact between the Coburn and the overlying Reedsville is gradational. At the contact, two- to four-inch-thick layers of dark-gray limestone alternate with one- to two-inch-thick layers of dark-gray calcareous shale.

The Coburn, Salona, and Nealmont Formations are exposed in the New Enterprise Limestone quarry at Ashcom. Thompson (1961) has described the Coburn and Salona Formation in the Ashcom quarry. A detailed description of the Rodman, Centre Hall, and Oak Hall Members of the Nealmont Formation is presented graphically in Figure 5 and is included in the Appendix.

Thompson (1961, p. 254) reports finding *Cryptolithis tesselatus* and *Homalonotus trentonensis* in the Salona limestone at Ashcom; both are diagnostic fossils for the Trenton Group and indicate an upper Middle Ordovician age for these beds.

The Trenton Group correlates with the upper Chambersburg and the lower Martinsburg Formations of southeastern Pennsylvania (Twenhofel and others, 1954).

Reedsville Formation

In the western half of the study area, the Reedsville Formation (Ulrich, 1911) crops out as a continuous band along the eastern and western margins of Snake Spring Valley and along the eastern margin of

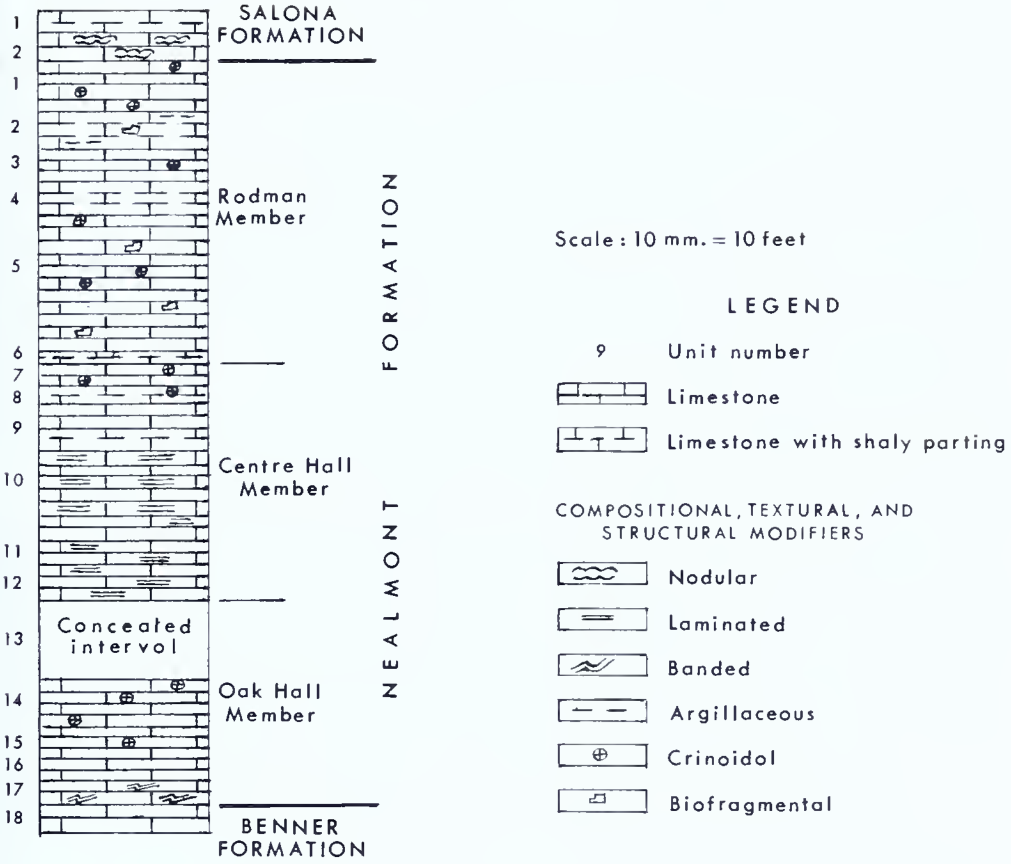

Figure 5. Detailed columnar section of the Nealmont Formation exposed in the New Enterprise quarry at Ashcom.

Morrison Cove. In the northern part of the area, the Reedsville Formation is exposed at the core of the breeched Warrior Ridge anticline and south of Henrietta as an isolated patch along the western side of Tussey Mountain. The Reedsville Formation forms a rolling, knobby, grass-covered surface upon which a shaly soil has developed.

The thickness of the Reedsville Formation, as measured along the north side of U.S. Route 30 west of Mount Dallas, is 1310 feet thick.

The upper and lower contacts of the Reedsville Formation are gradational. For mapping purposes, the lower contact was drawn at the change from the platy limestone float of the Trenton Group to the shaly soil of the Reedsville. The upper contact was drawn at the change from the shaly soil of the Reedsville to the sandstone float of the overlying Bald Eagle Formation. A break in slope also marks the contact between the Reedsville and the Bald Eagle.

The Reedsville Formation is an interstratified sequence of dark-gray, dark-brownish-gray, dark-greenish-gray, and olive-gray shales and mudstones with some 1- to 5-inch-thick interlayers of similarly colored siltstone and very fine-grained sandstone. The sandstone layers are generally laminated and cross-bedded. Towards the top of the Reedsville, the siltstones and sandstones become thicker and more numerous. The very top of the Reedsville Formation is marked by a 35-foot-thick, massive, dark-gray, very fine-grained sandstone unit. This thick-bedded sandstone unit, which is well exposed on Pa. Route 886 in Loysburg Gap, contains several *Orthorhynchula* zones and up to twenty 2- to 3-inch-thick zones of poorly preserved gastropods and unidentified brachiopods. These fossiliferous zones are ankeritic, and weather to a rust-brown color. Near the base of the Reedsville the dark-gray shales become calcareous. Near the contact between the Reedsville Formation and the underlying Trenton Group, 1- to 2-inch-thick layers of dark-gray, fine-grained limestone alternate with 2- to 4-inch-thick layers of calcareous shale.

The presence of the brachiopod *Orthorhynchula* and the gastropod *Sinuites* (?) indicates a lower Upper Ordovician (Edenian) age for the upper part of the Reedsville Formation. Twenhofel and others (1954) correlated the Reedsville with upper Martinsburg Formation of southeastern Pennsylvania.

Bald Eagle Formation

The Bald Eagle Formation (Grabau, 1909) was subdivided by Swartz (1955, p. S10, S11) into a lower sandstone and shale member and an upper sandstone member. Both members are present in the study area. Swartz (1955) named the lower member Centennial School and the upper member Spring Mount. These names are not yet accepted by the Pennsylvania Geological Survey because they have not been formally proposed.

The Bald Eagle Formation is exposed along the eastern flank of Evitts Mountain, the western flank of Tussey Mountain, and as a continuous band surrounding the core of the breached Warrior Ridge anticline. Excellent exposures of the Bald Eagle occur at Loysburg Gap, at Everett Gap, and at Bedford Narrows. The Bald Eagle Formation is more resistant to erosion than either the underlying Reedsville or the overlying Juniata Formations, and forms a subsequent ridge on the anticlinal side of Evitts and Tussey Mountains.

At Loysburg Gap the Bald Eagle Formation is 532 feet thick. Of this, the lower sandstone and shale member is 242 feet thick, and the upper sandstone member is 290 feet thick.

The lower contact was placed at the change in float from the shale chips of the Reedsville Formation to the sandstones of the Bald Eagle Formation. The upper contact was drawn at the change in soil color from the gray-brown soil of the Bald Eagle to the grayish-red soil of the Juniata Formation.

The upper member of the Bald Eagle Formation is composed of 1- to 6-foot-thick layers of platy- to thick-bedded, commonly laminated and cross-bedded, light-olive-gray, medium- to fine-grained, low-rank graywacke and quartzose graywacke sandstones. Interstratified with the light-olive-gray sandstones are brownish-gray and greenish-gray sandstones of similar composition and grain size. At Bedford Narrows several reddish-gray sandstone layers occur at about the middle of the upper member. The contact with the overlying Juniata Formation is gradational. The light-olive-gray sandstones of the upper member are interbedded with the reddish-gray sandstones of the Juniata Formation.

The lower sandstone and shale member is similar to the upper member except that 6- to 24-inch-thick layers of olive-gray, greenish-gray, and brownish-gray shale are interbedded with the sandstones. Clay galls are common on the bedding plane surfaces of the sandstones. Beginning about 75 feet above the base of the lower member are six 1- to 5-foot-thick layers of reddish-gray shale. Associated with these shales are reddish-gray and greenish-gray sandstones and siltstones. At the base of the lower member a thick-bedded, light-olive-gray, cross-bedded and laminated sandstone rests with sharp contact upon the massive, dark-gray, fine-grained, *Orthorhynchula*-bearing sandstone of the uppermost Reedsville Formation.

The sandstones of the Bald Eagle Formation as studied in thin section fall into two classes, low-rank graywackes and quartzose graywackes.

The low-rank graywacke is a medium- to fine-grained, well- to moderately well-sorted sandstone, composed of subangular to subrounded grains of quartz, feldspar, and metamorphic rock fragments in a chlorite-sericite matrix. The quartz, which accounts for 48 percent to 58 percent of the rock, occurs as elliptical to shard-like grains that show a normal to undulose extinction and generally few inclusions. Silica overgrowths are not common. The feldspars (2 to 3 percent of the rock) include plagioclase and very fresh to partly sericitized microcline. The metamorphic rock fragments (3 to 10 percent of the rock) are metaquartzites, slate, and phyllites. The matrix (23 to 25 percent of the rock) consists of clots and stringers of sericite and chlorite.

The quartzose graywacke is similar to the low-rank graywacke except that the quartz content is higher and the amount of matrix lower. The composition is: quartz, 59 to 68 percent; feldspar, 1 to 5 percent; metamorphic rock fragments, 2 to 12 percent; a few grains of illite-bearing chert; and a chlorite-sericite matrix, 12 to 22 percent. Much of the quartz shows silica overgrowths in optical continuity with the grains.

No fossils were observed in the Bald Eagle Formation. The Bald Eagle is correlated with the Oswego Sandstone of New York and West Virginia on the basis of stratigraphic position (Twenhofel and others, 1954).

Juniata Formation

The Juniata Formation (Darton and Taff, 1896) was subdivided by Swartz (1955, p. S10, S11) into three members, an upper red sandstone member, a middle red sandstone and mudstone member, and a lower red sandstone member. These were informally named by Swartz (1955) the Run Gap, Plumber Hollow and East Waterford Members, respectively. All three are present in the study area.

The Juniata is exposed along the eastern flank of Evitts Mountain, along the western flank of Tussey Mountain, and below the ridge crest surrounding the breached Warrior Ridge anticline. The Juniata Formation is slightly less resistant to erosion than either the underlying Bald Eagle Formation or the overlying Tuscarora Formation and consequently forms a topographic low between the main Tuscarora ridge and the subsidiary ridge formed by the Bald Eagle Formation.

Excellent exposures of the Juniata Formation occur along the Pennsylvania Turnpike at Bedford Narrows, Everett Narrows, and Loysburg Gap.

At Loysburg Gap, the Juniata Formation is 1028 feet thick. The following tabulation shows the thickness of the members of the Juniata Formation at this locality:

Tuscarora Formation	
Juniata Formation	
upper member	175 feet
middle member	427 feet
lower member	426 feet
Bald Eagle Formation	

The lower contact was placed at the change in soil color from the brownish-gray soil of the Bald Eagle Formation to the reddish-gray soil of the Juniata Formation. The upper contact is generally concealed by a thick mass of Tuscarora scree. The contact was drawn just below the crest of the Tuscarora Sandstone ridge.

The lowermost member is composed of alternating sandstones and shale layers in the ratio of about 9 to 1. The member consists of 1- to 10-foot-thick layers of medium- to thick-bedded, commonly laminated and cross-bedded, reddish-gray, fine- to medium-grained, low rank graywacke and quartzose graywacke sandstone. Interstratified with the sandstones are 1- to 4-foot-thick layers of reddish-gray shales and silty shales, and 4- to 12-inch-thick layers of greenish-gray siltstones. The lower member grades up into the middle member.

The middle member is composed of interbedded sandstones and shales in the ratio of about 4 to 6. The lower portion of the member contains 1- to 10-foot-thick layers of reddish-gray shale and mudstone interstratified with 2- to 4-foot-thick layers of commonly cross-bedded or laminated, reddish-gray sandstone. The upper portion of the middle member contains reddish-gray shales and mudstones interstratified with 2- to 6-inch-thick, reddish-gray sandstones. It has a sand to shale ratio of 1 to 5. Several of the sandstone beds contain silt-filled *"Scolithus"* tubes.

The upper member is composed of reddish-gray and pinkish-gray, commonly laminated or cross-bedded, thick-and thin-bedded, medium- to fine-grained, protoquartzite and orthoquartzite sandstones. At the base of this member several olive-gray sandstones interbed with the reddish-gray sandstones.

The upper contact of the Juniata with the overlying Tuscarora Formation is gradational; reddish-gray and pinkish-gray sandstones interbed with the whitish- and tannish-gray sandstone of the Tuscarora. The basal contact of the Juniata Formation is also gradational; here the reddish-gray sandstones of the lower member interbed with the greenish-gray and light-olive-gray sandstones of the Bald Eagle Formation.

Petrographically, the sandstones of the lower and middle members of the Juniata are composed of low-rank graywackes and quartzose graywackes. These sandstones are similar in composition to the Bald Eagle sandstones with the exception that the Juniata contains from 1 to 4 percent hematite and up to 15 percent ankerite. The low-rank graywacke of the Juniata Formation is a moderately sorted, medium- to very fine-grained sandstone containing 55 to 59 percent quartz, 1 to 2 percent feldspar, 1 to 2 percent mega-micas (biotite and muscovite), and 7 to 14 percent metamorphic rock fragments, in a matrix (21 to 24 percent) of chlorite and sericite. The angular to subrounded quartz grains are elliptical to shard-like and show a normal to wavy extinction. A few of the quartz grains are rutilated and some contain vermiculated chlorite. The feldspar include microcline and fresh to highly sericitized plagio clase (albite?). The metamorphic rock fragments include partly chloritized metaquartzites, slates, and phyllites. The hematite occurs as small grains impregnated in the matrix and as partial coatings on the detrital grains.

The quartzose graywacke of the Juniata Formation is a medium- to fine-grained sandstone composed of 68 percent quartz, 2 percent feldspar, 13 percent metaquartzite rock fragments, 11 percent phyllite and slate rock fragments, and a few grains of chert, in a matrix of chlorite and sericite. The quartz type and feldspars are similar to the low-rank graywackes. The main difference between the low-rank graywacke and the quartzose graywacke of the Juniata Formation is that the latter appears better sorted and contains more metamorphic rock fragments and less matrix than the former.

Olive-gray, reddish-gray, and pinkish sandstones from the upper member of the Juniata were studied. The upper member sandstones are protoquartzites, transitional in composition between the graywackes of the lower Juniata and the orthoquartzites of the Tuscarora. The protoquartzites are medium- to fine-grained sands containing 78 to 85 percent quartz, 0 to 2 percent micaceous metamorphic rock fragments, and 2.5 to 3.5 percent metaquartzite rock fragments, in a matrix (8 to 15 percent) of chlorite and sericite. Silica overgrowth occur on many of the grains. In the reddish-gray and pinkish sandstones the matrix is impregnated with red translucent hematite.

The quartz types and the rock fragments suggest that the provenance for the Juniata sandstones was a low-rank metamorphic terrane composed of slate, phyllite, and metaquartzites, with some igneous intrusives to account for the rutilated quartz and the microline feldspars.

No fossils other than some "*Scolithus*" tubes were found in the Juniata Formation. Rogers (1953, p. 97-98) reports that in eastern Tennessee the Juniata Formation intergrades laterally with the marine Sequatchie Formation. The Sequatchie Formation contains a fauna which indicates an Upper Ordovician (Richmondian) age for the unit.

SILURIAN SYSTEM

Tuscarora Formation

The Tuscarora Formation (Darton and Taff, 1896) crops out along the crest of the ridge surrounding the breached Warrior Ridge anticline and underlies the prominent ridges of Evitts and Tussey Mountains. The Tuscarora is partially exposed in the gaps at Everett, Bedford, and Loysburg where it is 525 feet thick.

The lower and upper contacts of the Tuscarora Formation are concealed beneath a scree of Tuscarora sandstone and must often be approximately located. The lower contact with the Juniata Formation is drawn on the obsequent slope just below the crest of the Tuscarora sandstone ridge. The upper contact is drawn at the break in slope between the Tuscarora and Rose Hill Formations.

The Tuscarora Formation is composed of 2- to 8-foot-thick layers of medium- and thick-bedded, hard, whitish, medium- to fine-grained orthoquartzite sandstones. The bedding is rough-surfaced, irregular, curving, and spaced 8 to 24 inches. The beds generally are laminated and cross-bedded. The lamination and cross-bedding show up as thin, gray- or rust-colored markings. The cross-bedding has an amplitude of from 3 inches to 3 feet and a predominantly westward slope. The uppermost 50 feet of the Tuscarora is composed of alternating 2- to 8-foot-thick layers of thick- and thin-bedded, brownish- and gray-colored, cross-bedded, iron-stained orthoquartzites. *Arthrophycus* is found in these beds. Near the base thick-bedded, brownish-colored sandstones appear and interbed with whitish-, pinkish-, and purple-colored sandstones. The contact between the Tuscarora Formation and the Juniata Formation is gradational. The contact between the Tuscarora sandstone and the overlying Rose Hill Formation is everywhere concealed. It is apparently sharp, however, because the change from sandstone to shale occurs over a very short interval.

Thin-section examination of the Tuscarora shows that it is a very pure, medium- to fine-grained, well to moderately sorted orthoquartzite, containing about 90 percent detrital quartz, 6 to 7 percent silica cement, 3 percent metaquartzite rock fragments, a few illite-bearing grains of chert, a trace of sericite, and a trace of leucoxene and hematite. The subrounded to rounded quartz grains, which show a normal to wavy extinction, are relatively high in vacuoles and bubble trains. Some of the vacuoles and bubble trains appear to be inherited from the source area, and some, which can be traced across several grains, appear to be due to the deformation of the Tuscarora sandstone. Silica overgrowths, in optical continuity, have resulted in an interlocking mosaic of grains with sharp straight contacts.

No fossils other than *Arthrophycus* were found in the Tuscarora Formation. Butts (1940, p. 235) reports that in western Virginia, the Clinch (Tuscarira equivalent, Butts, 1940, p. 229) passes into a marine facies that contains fossils of a lower Silurian (Albion) age.

Rose Hill Formation

Exposures of the Rose Hill Formation (Swartz, 1923) parallel those of the Tuscarora and can be traced as a continuous band along the eastern flank of Tussey Mountain, around the nose of the Warrior Ridge anticline and along the eastern flank of Warrior Ridge. The Rose Hill Formation is not resistant to erosion and consequently occupies a topographic low between the prominent Tuscarora sandstone ridge and the much lower ridge supported by the Keefer Member of the Mifflintown Formation. Exposures of the Rose Hill are poor. At Loysburg Gap the measured thickness of the Rose Hill Formation is 575 feet.

The lower contact of the Rose Hill Formation was drawn at the prominent break in slope between the Tuscarora Formation and the shales at the base of the formation. The upper contact was drawn at the base of the Keefer.

The Rose Hill Formation is a variegated shale and mudstone sequence with thin sandstone and siltstone layers in the middle portion of the unit. The upper quarter of the Rose Hill Formation is composed of grayish-olive shales and chocolate-brown, pinkish-weathering shales and mudstones. The remainder of the Rose Hill Formation consists of 4- to 8-foot-thick layers of dusky-yellow-brown, grayish-olive, and pale-olive shales and mudstone with interbeds of chocolate-brown shales in the middle portion and purplish-gray shales in the lower portion. Beginning about 150 feet below the top of the formation and extending down to about the middle of the formation, there are 1- to 2-inch-thick layers of laminated, olive- and yellow-brown sandstones and siltstones interbedded with the shales. On weathering, the shales frequently become iron-stained. The base of the Rose Hill Formation contains several thin, laminated and cross-bedded, purplish, ferruginous sandstones.

The very top of the Rose Hill Formation contains a thin-bedded, 1-foot-thick, highly fossiliferous, ferruginous, limestone and calcareous shale. This ferruginous layer imparts a blood-red stain to the overlying soil and is helpful in locating the upper Rose Hill contact.

Some layers of the Rose Hill Formation are highly fossiliferous. Among the fossils collected, as identified by the writer, were crinoid plates, *Mastigobolbina typus, Mastigobolbina modesta, Mastigobolbina bifida, Zygobolbina excavata, Zygobolba excavata, Zygobolba rectangula, Coelospira hemispherica, Bonnemaia rudis, Calymeme macrocephala, Chonetes,* and *Tentaculites.* This assemblage is characteristic of the Rose Hill shale (Swartz, 1958) and indicates a Middle Silurian (Niagaran) age for these beds.

Swartz and Swartz (1931, p. 660) correlate the Rose Hill shale with the "Clinton" beds of eastern Pennsylvania and these in turn with the Shawangunk Formation at the Delaware Water Gap.

Mifflintown Formation

Miller and Conlin (1961, p. 2) proposed that the Silurian Keefer sandstone and the Rochester and McKenzie Formations of previous workers be combined into a single formation under the name of Mifflintown Formation. The three units were retained as members within the Mifflintown Formation. The definition of Miller and Conlin is applicable in this part of south-central Pennsylvania because the Rochester cannot be distinguished from the McKenzie without the aid of fossils and because the Keefer is too thin to map as a separate unit.

Within the McKenzie Member there is a sequence of red shales to which Swartz (1923, p. 36) assigned the name Rabble Run Member.

The Rabble Run Member was mapped locally to determine the size and extent of folding in the upper portion of the Mifflintown Formation.

East of Loysburg Gap, the Mifflintown Formation is 435 feet thick. The following tabulation gives the thickness of the subdivisions of the Mifflintown Formation at this locality:

Upper McKenzie Shale and Limestone Member	70 feet
Rabble Run Member	88 feet
Lower McKenzie and Rochester Shale and Limestone Members (undivided)	270 feet
Keefer Sandstone Member (concealed here, based on several measurements in area)	3-10 feet

The Mifflintown Formation is slightly less resistant to erosion than either the basal Keefer Member or the overlying Bloomsburg Formation and forms a slight topographic low between these two units. The Mifflintown crops out as a continuous northeastward-trending band along the base of the eastern flank of Tussey Mountain and Warrior Ridge.

The lower contact was drawn at the base of the Keefer sandstone, or where the Keefer is very thin and largely concealed, at the blood-red stained soil formed by the ferruginous limestones at the top of the Rose Hill Formation. The upper contact was drawn at the change in float from the olive-gray shales of the Mifflintown Formation to the grayish-red siltstones of the Bloomsburg Formation.

The lowermost or Keefer Sandstone Member is composed of medium-dark-gray, fine-grained, calcareous sandstones. On weathering these sandstones become punky and take on a dark-yellow-orange or yellow-brown color. Extending southward from just north of Yellow Creek and associated with the calcareous sandstones of the Keefer are thin beds of whitish, medium-grained, ankerite-stained, siliceous orthoquartzite. Folk (1960), reports that the Keefer consists of two phases: a coarser grained, silica-cemented eastern phase, representing the near shore environment; and a finer grained, calcareous-cemented western phase, representing the offshore environment. Both phases appear to be present in the map area.

The upper and lower McKenzie and the Rochester Shale and Limestone Members are lithologically similar units. The members consist of alternating 2- to 10-foot-thick layers of pale-olive, greenish-gray, dark-yellowish-brown shales, interstratified with several 4- to 8-foot-thick layers of dark-gray, calcareous shale and platy-weathering, fine-grained limestone. The dark-gray layers appear to weather in two stages, first to an olive gray and then to a tannish-gray color. In the southern part of the map area, the shales of the Mifflintown Formation become increasingly calcareous, and in the vicinity of Everett, the Mifflintown Formation is largely composed of variegated calcareous shales.

The Rabble Run Member is composed of reddish-brown, noncalcareous shales and thin siltstones. From Loysburg southward the Rabble Run Member splits into two equally thick red shale units separated from each other by a 6-foot layer of pale-olive, calcareous shale.

In material collected from just above the Keefer Member, the writer identified *Atrypa reticularis, Stegerhynchus neglecta, Lingula, Drepanellina clarki, Paraechmina postica, Encrinurus ornatus,* and *Brachyprion proutyi.* This assemblage (Swartz, 1958) characterizes the Rochester Member of the Mifflintown Formation and indicates a Middle Silurian age for these beds. From the lower McKenzie Member the writer identified *Eukloedenella sinuata, Kloedenella gibberosa,* and *Dizygopleura* sp.

Swartz and Swartz (1931, pp. 659, 660) correlated the upper McKenzie, Rabble Run, and tentatively the lower McKenzie Members of the Mifflintown Formation with the lower portion of a much-thickened section of the Bloomsburg Formation to the east. These same investigators also correlated the Rochester Shale Member and the Keefer Sandstone Member of the Mifflintown Formation with the "Clinton" strata of eastern Pennsylvania.

Bloomsburg Formation

The Bloomsburg Formation (White, 1883) crops out as a narrow, continuous band along the eastern flank of Tussey Mountain and Warrior Ridge. In Yellow Creek Valley the Bloomsburg Formation is exposed in a series of intricate folds on the eastern and western flanks of the Yellow Creek syncline.

The Bloomsburg Formation is more resistant to erosion than are the enclosing shale formations and forms a long, narrow, almost continuous ridge. The presence of the Bloomsburg Formation is indicated by a narrow, tree-covered ridge that is easily traceable on aerial photographs. The shale areas on either side of the ridge have generally been cleared for farming.

The contact between the Mifflintown Formation and the Bloomsburg Formation is sharp and easily located. The contact between the Bloomsburg Formation and the Wills Creek Formation is gradational and was drawn at the first appearance of the green and gray shales of the Wills Creek Formation above the main body of the Bloomsburg Formation.

The Bloomsburg Formation is composed of grayish-red shale and mudstone. At the middle and at the base of the formation, there is a 6- to 10-foot-thick, medium- to thick-bedded, very fine-grained, reddish-gray sandstone. The Bloomsburg Formation may be divided in to four units: a lower sandstone, a middle shale, an upper sandstone, and an upper shale. Locally, the base of the middle shale and the top of the lower sandstone contain thin limonite- and ankerite-stained beds. In Yellow Creek Valley some of the grayish-red-colored sandstones and shales change laterally to a dusky-yellow-green color, and some of the grayish-red beds contain streaks and mottles of dusky yellow green. The lateral variation in the color of the Bloomsburg Formation is illustrated in two measured sections presented in the Appendix.

Petrographically the grayish-red sandstones of the Bloomsburg are hematitic protoquartzites and quartzose graywacke composed of quartz grains and micaceous or metaquartzite rock fragments in an illite-chlorite matrix. The sandstone contains 73 to 85 percent detrital quartz, 10 to 18 percent illite-chlorite, 6 to 8 percent hematite, and some leucoxene. The moderately well-sorted, subangular to subrounded quartz grains are low in inclusions and show a normal to wavy extinction. In the samples examined the ratio of normal to wavy quartz was about 2 to 1.

Silica overgrowths occur on many of the quartz grains. On some of the quartz grains which show silica overgrowths the original shape of the grain is outlined by a hematite coating.

Hematite occurs as partial coatings on some quartz grains, as small rounded grains impregnated in the matrix, and as clots of hematite filling the pore space between the grains. If all the hematite in the Bloomsburg were authigenic, two stages of formation would be required to explain the observed occurrence. The hematite coating under silica overgrowths, however, would suggest that at least part of the iron in the Bloomsburg was introduced with the quartz grains.

The dusky-yellow-green sandstones of the Bloomsburg are similar to the grayish-red sandstones with the exception that the former contain less hematite (2 to 3 percent) and more illite-chlorite matrix (18 to 23 percent). The hematite is not evenly distributed throughout the matrix but occurs as isolated clots of relatively large grains. The dusky-yellow-green sandstones contain the same quartz types and matrix as that found in the grayish-red sandstones.

No fossils were found in the Bloomsburg Formation. Swartz (1934, p. 3) assigned the Bloomsburg Formation to the base of the Cayugan Series and an Upper Silurian age.

Wills Creek Formation

The Wills Creek Formation (Uhler, 1905) crops out as a continuous band along the base of the eastern side of Tussey Mountain and Warrior Ridge and in the central portion of Yellow Creek Valley. The exposure is generally poor. The Wills Creek underlies much of the cultivated land in Yellow Creek Valley and forms a low, rolling surface that is frequently strewn with greenish-gray calcareous shale chips. North of Cypher the Wills Creek is 480 feet thick.

The contact with the Bloomsburg Formation is gradational and was drawn at the stratigraphically lowest occurrence of the greenish-gray Wills Creek shales. The contact with the overlying Tonoloway appears to be sharp. This contact was drawn either at the grayish orthoquartzite marking the top of the Wills Creek Formation in some areas, or at the change from the greenish-gray calcareous shales of the Wills Creek to the platy-weathering, laminated limestones of the Tonoloway Formation.

The Wills Creek Formations is composed of 1- to 10-foot-thick layers of pale-olive and greenish-gray, calcareous shales and mudstones. Interbedded with the calcareous shales and mudstones are dark-gray, calcareous and noncalcareous shales and thin-bedded, laminated limestones. At the top and near the base of the formation the dark-gray beds predominate. In the middle portion of the formation there are several thin layers of cross-bedded, limonite-stained orthoquartzite. In Yellow Creek Valley, the greenish-gray calcareous shales of the Wills Creek Formation are often red splotched, and reddish-gray calcareous shales intercalate with the greenish-gray beds. North of Cypher, the top of the Wills Creek is marked by several thin layers of medium-gray, cross-bedded and laminated, siliceous and calcareous orthoquartzite. South of Cypher, these sandstones are missing, and the dark-gray, calcareous shales of the upper Wills Creek lie in sharp contact with the thin-bedded, laminated limestones of the Tonoloway Formation.

The only fossils found in the Wills Creek are a few specimens of the ostracod, *Leperditia*. Swartz and Swartz (1931, p. 660) assigned an Upper Silurian age to the Wills Creek Formation and correlated it with a portion of a much-thickened Bloomsburg Formation in eastern Pennsylvania. In the study area, the red shales of the Wills Creek may represent the local intertonguing of these two facies.

Tonoloway Formation

The Tonoloway Formation (Ulrich, 1911) parallels the exposure of the Wills Creek Formation. The Tonoloway crops out as a continuous band along the base of the eastern side of Tussey Mountain and Warrior Ridge and as isolated patches in Yellow Creek Valley. Exposures are generally poor.

The Tonoloway and the Wills Creek together form the low, rolling, ,cultivated belt between the Bloomsburg Formation and the Ridgeley sandstone ridge. The exposure of the Tonoloway Formation is marked by a platy limestone float. Northwest of Cypher the Tonoloway is 460 feet thick.

A break in slope marks the contact between the Tonoloway and the overlying Keyser Formation. The contact with the underlying Wills Creek was described earlier.

The Tonoloway Formation is largely composed of 1- to 6-foot-thick layers of dark-gray, finely laminated, thin-bedded, pure to argillaceous limestone. These beds alternate with layers of thicker bedded, laminated and nonlaminated limestones. There are some intraformational conglomerates. Near the top, middle, and lower portions of the Tonoloway, the limestones are replaced by calcareous dolomites. Near the base and about 100 feet below the top of the formation, light-olive-gray, thin-bedded, argillaceous limestones intercalate with the nonargillaceous, dark-gray limestones. Dark-gray, dense cherts and light-gray, cellular cherts occur near the top of the Tonoloway Formation. Near the base of the Tonoloway limestone there are pinkish, yellowish-brown and light-gray cherts. From Yellow Creek southward, the lower portion of the Tonoloway becomes increasingly argillaceous, and platy-weathering limestones are seen to alternate with brownish-, pale-olive-, and yellowish-brown-weathering, calcareous shales.

Petrographically, the finely laminated, dark-gray limestone of the Tonoloway is composed of thin layers of calcilutite, alternating with thin layers of calcilutite and euhedral dolomite. The lamination reflects the variation in dolomite. The dolomite is authigenic and occurs intimately mixed with the calcilutite.

The thicker bedded, unevenly laminated and nonlaminated limestones consist in part of pellet limestones. In thin section the pellet limestone is composed of small (0.05 to 0.08 mm) structureless pellets, or a combination of pellets and bioclasts, in a partially recrystallized calcilutite matrix.

The Tonoloway is sparingly fossiliferous. In material collected, *Dizygopleura halli, Leperditia sp., Welleria obliqua, Hormotoma rowei,* and *Stegerhynchus* (?) *tonolowayensis* have been identified. Stose and Swartz (1912, p. 7) assigned the Tonoloway limestones to the upper portion of the Cayugan Series and an Upper Silurian age. Swartz and Swartz (1931, p. 660) correlated the Tonoloway Formation with the upper portion of a much-thickened Bloomsburg section to the east.

Keyser Formation*

The Keyser Formation (Ulrich, 1911) crops out as a narrow, continuous, northeastward-trending band along the eastern side of Tussey

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* The description of this formation was written by D. M. Hoskins of the Pennsylvania Geological Survey based on his field work in the Everett area. The petrographic data and the detailed section of the Keyser Formation is based on the work of the author.

Mountain and Warrior Ridge. In central Pennsylvania, F. M. Swartz (1955, p. S7) divided the Keyser Formation into three members. In ascending order the members are a lower nodular limestone member, a middle limestone member, and an upper laminated limestone member. These three units may be present in the map area. Swartz informally applied the names Mount Rock, Hollidaysburg and Paintersville to these members.

The Keyser Formation makes a small bench on an otherwise straight slope leading from the Tonoloway Formation to the crest of the Ridgeley sandstone ridge. The Keyser on weathering produces a nodular and platy limestone float containing abundant stromotoporoids and some chert. At Everett the Keyser is about 200 feet thick.

The contact between the Keyser and the Tonoloway Formations is marked by a break in slope. The upper contact of the Keyser was drawn at the change from the cherty float of the overlying Old Port Formation to the platy limestone float of the upper Keyser.

The basal portion of the Keyser Formation is largely composed of medium- to thin-bedded, dark-gray, nodular limestones. The nodules are composed of a fine-grained limestone that often contains whitish or black, recrystallized bioclasts. Interstratified with these nodular limestones are dark-gray, thin-bedded, finely laminated limestones and thick-bedded, partially bioclastic limestones. At the north end of the map area, the lower portion of the lower member contains medium-gray and pale-brownish-gray, coarsely crystalline, crinoidal limestones.

The middle portion of the Keyser Formation is transitional in character between the nodular beds of the lower portion and the laminated beds of the upper portion. The middle portion is thick-bedded, cherty and arenaceous and shows cross and convolute laminations.

The upper portion of the Keyser is composed of finely laminated, dark-gray, thin-bedded limestones and thick-bedded, massive nonlaminated limestones. On weathering, the laminated limestones produce a pale-red-colored, platy limestone float. There are some medium-gray to dark-gray cherts in the lower portion of the member. The upper 47 feet contains several argillaceous and fossiliferous beds.

The contact of the Keyser and Tonoloway is difficult to place because of its transitional and seldom-exposed nature. It has been drawn at the stratigraphically highest occurrence of the thin-bedded, finely laminated, Tonoloway-type limestone. The upper contact is sharp and is drawn at the first appearance of the distinctive brachiopod *Gypidula* in bioclastic and cherty limestone above the finely laminated limestone of the upper part of the Keyser Formation.

The Keyser Formation and the lower portion of the overlying Old Port Formation are partially exposed at Everett, on U.S. Route 30 in the old quarry opposite the bridge across the Raystown Branch of the Juniata River. The Keyser Formation may also be seen in an old quarry located about 2000 feet south of the Everett quarry. The Keyser was measured at Everett. These data are presented graphically in Figure 6 and a detailed written description is included in the Appendix.

Thin sections from the nodular beds of the lower Keyser were examined. The composition of the nodules and the matrix varied with the sample being examined. However, within the same thin section there is a marked difference in composition between the matrix and the nodules. In general, the matrix contains a larger amount of clastic elements. The nodules of the lower Keyser are elongate, round to subangular bodies composed of either (1) calcilutite with some bioclasts and pellets (pellets and bioclasts represent 5 or 40 percent of the sediment), or (2) calcarenite with very few bioclasts.

In some of the calcilutite nodules there are thin, dark, shear planes aligned parallel to the edge of the nodule. These shear planes indicate slippage within the nodule and suggest that the nodules were semi-consolidated when formed. In some cases evidence that the nodules have been pulled apart was seen in the matching of serrated edges across a zone filled with matrix or sparry calcite.

The matrix occurs as thin and thick, wavy bands that often show a flow banding parallel to the outline of the nodule. The matrix is composed of argillaceous calcilutite with quartz silt and/or pellets and recrystallized bioclasts in a calcilutite groundmass, or both.

The difference in composition between the matrix and the nodules appears to have been an important factor in the formation of these nodular limestones. The following model is suggested. The original sediment consisted of layers of semi-consolidated calcilutite or calcarenite, alternating with layers of unconsolidated, argillaceous calcilutite or pelletic-bioclastic lime mud. Due to deposition on a sloping surface or the weight of the overlying sediment, movements within the sediment took place. The semi-consolidated layers were broken into nodular-shaped bodies and the more fluid, clastic-rich layers were injected between the nodules. The extent of rounding and the shape of the nodules depend upon the viscosity of the semi-consolidated layer and upon the amount of rotation between the nodules.

From the Keyser Formation, the writer identified stromatolites, bryozoa; the ostracodes *Dizygopleura* sp., *Zygobeyrichia barretti* (?), and *Leperditia* sp., the brachiopods *Stenocisma deckerensis, Merista typa,*

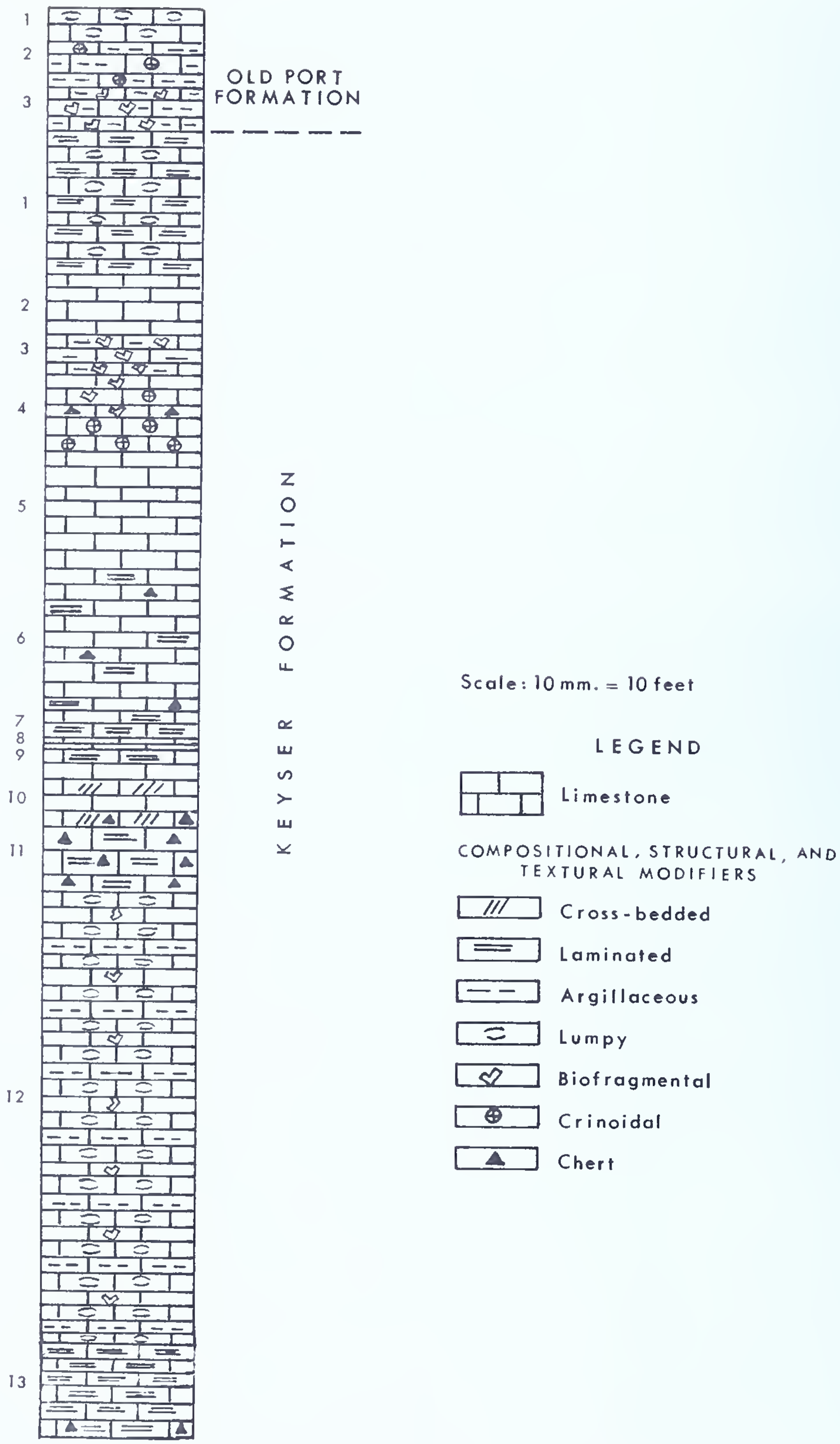

Figure 6. Detailed columnar section of the Keyser Formation and the lower part of the Old Port Formation exposed in the vicinity of Everett.

Camarotoechia sp., and *Chonetes jerseyensis;* the coelenterates, *Stromatopora* sp., *Favosites* sp., and *Synaptophyllum* (?).

Based on a restudy of the brachiopods and a comparison with the European type sections, Boucot (1957, p. 1702) suggests that the Silurian-Devonian systemic boundary occurs in the upper part of the Keyser Formation.

Swartz (1939, p. 46) correlates the Keyser Formation with the Decker, Roundout, and Manlius Formations of eastern Pennsylvania and New Jersey.

DEVONIAN SYSTEM

Old Port Formation*

The Old Port Formation (Conlin and Hoskins, 1962) includes the units earlier called the "Helderberg" and "Oriskany Groups". The formations included in these groups—Coeymans, New Scotland, Shriver, and Ridgeley—have proved, with the exception of the Ridgeley in some areas, to be largely unmappable over large areas in central Pennsylvania. The formations are thin units and generally occur along a chert-strewn slope where contacts are invariably concealed. Accordingly, the formations are reduced to member rank. In some areas, one unit, usually the Ridgeley, may be mappable; the three remaining members are combined as a second map unit (Dyson, 1963, Plate 1).

The Old Port Formation in the Everett area consists of two mappable units, the Ridgeley Member at the top and a lower unit, the combined Shriver, "New Scotland" and "Coeymans" Members.

The Old Port Formation occurs as a narrow, continuous, northeastward-trending band paralleling the eastern boundary of the map area. Exposure of the lower unit is poor. The best exposures are along the Pennsylvania Turnpike south of Everett. Exposure of the Ridgeley Member is good; sand quarries at Everett and Tatesville expose large portions of the unit. South of Everett excellent exposures of the Ridgeley are found along the Pennsylvania Turnpike.

The Old Port Formation underlies the chert- and sandstone-strewn flank and crest of a sharp ridge. The Ridgeley Member is more resistant to erosion than the enclosing cherts, limestones and shales and consequently forms the crest of the narrow, continuous ridge which stands about 100 to 200 feet above the valley floor.

The contact of the Keyser Formation and the lower unit of the Old Port Formation was drawn at the change from platy-weathering limestones of the upper Keyser to the cherty soil of the Old Port. A distinctive break in the slope marks the contact between the lower unit and the Ridgeley Member and between the Ridgeley and the overlying Onondaga Formation.

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* The description of this formation was written by D. M. Hoskins based on his field work in the Everett area. The petrographic data and the detailed section of the Ridgeley Member is based on the work of the author.

The Ridgeley member is 111 feet thick near Everett and 122 feet thick west of Eichelbergertown. The lower unit of the Old Port Formation along the Pennsylvania Turnpike and in the quarries at the west end of Everett is 240 feet thick. The Shriver Member is 160 feet thick and the "New Scotland" and "Coeymans" Members together are about 80 feet thick.

The "Coeymans" and "New Scotland" limestones are poorly exposed along the north side of the Pennsylvania Turnpike starting at the east side of the abutment of the bridge that crosses the turnpike just south of Everett. The "Coeymans" Member is identified as the five feet of exposed cherty calcarenite that contains a few silicified specimens of *Gypidula coeymanensis* and numerous silicified specimens of *Atrypa reticularis.* This is overlain by 17 feet of bioclastic limestone that is largely composed of crinoid columnals and the coelenterate *Coenites.* This is in turn overlain by 30 feet of "reefy" limestone beds almost entirely composed of the coelenterates *Stromatopora* and *Favosites* with infillings of crinoid columnals and *Coenites.* A covered interval of 27 feet with scattered laminated calcilutite beds occurs between the reefy limestones and the siliceous shales and siltstones of the Shriver Member. The "Coeymans" and lower part of the "New Scotland" are also exposed at the east end of the large Keyser quarry in Everett.

The "Coeymans" and "New Scotland" limestones do not differ appreciably from many of the bioclastic and "reefy" limestones of the underlying Keyser Formation. Because of the classical treatment of these limestones as part of the "Helderberg" on the basis of included fossils they are separated from the Keyser Formation and placed in the Old Port Formation.

The Shriver Member as seen along the Pennsylvania Turnpike is composed of dark-gray, noncalcareous siliceous shale and mudstone that appears cherty. Locally, the lower portion of the Shriver weathers to produce a whitish unctuous clay. The Shriver on weathering produces an abundance of reddish-brown, pinkish, and tannish punky cherts.

From the "New Scotland" specimens of *Acrospirifer cyclopterus, Coelospira concava, Strophonella punctulifera, Meristella arcuata, Schuchertella* sp., and *Uncinulus* (?) have been collected. These fossils indicate a Lower Devonian age for these beds.

The Ridgeley Member is largely composed of 3- to 10-foot-thick layers of whitish to light-gray, medium-grained, calcareous and siliceous orthoquartzites. The beds are frequently laminated and cross-bedded. The cement from the calcareous sandstones has generally been leached, and these beds weather soft and crumbly with a whitish or very pale-orange

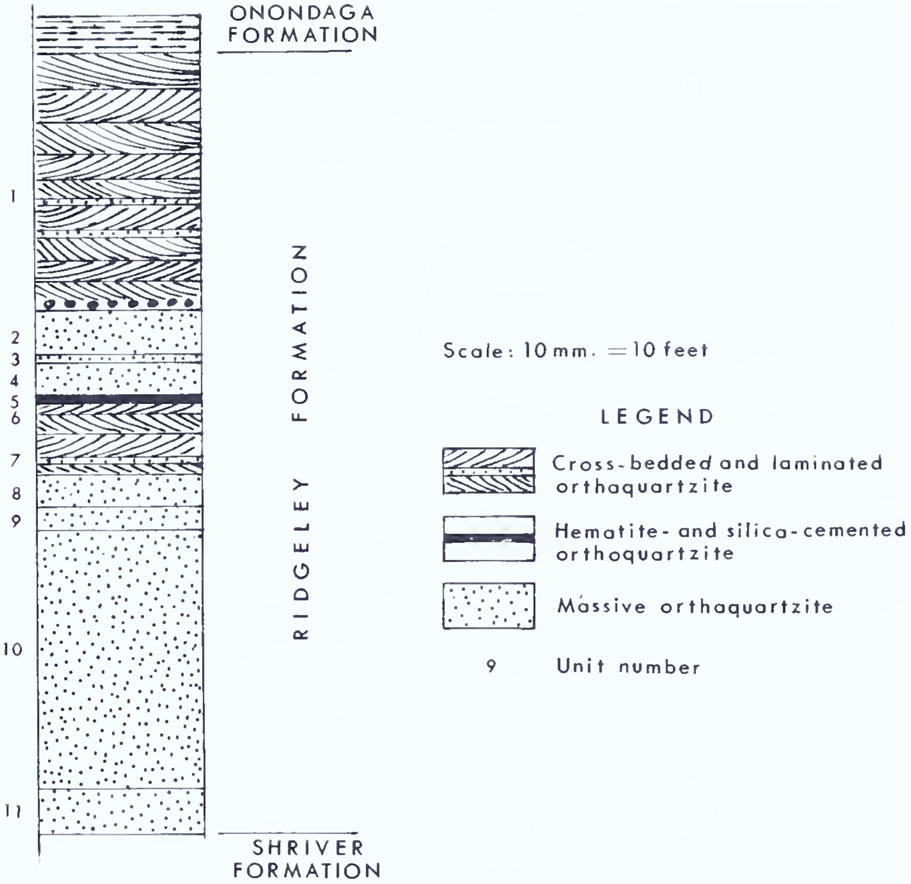


Figure 7. Detailed columnar section of the Ridgeley Member of the Old Port Formation exposed in Pennsylvania Turnpike cut at Everett.

color. In the vicinity of Cypher the middle portion of the Ridgeley contains several purplish-colored ferruginous orthoquartzites. From Yellow Creek southward the top of the Ridgeley is marked by a 2- to 3-foot-thick, very coarse-grained, siliceous orthoquartzite. Locally, this sandstone contains a ferruginous cement. At Everett, thick beds of laminated and cross-laminated, medium-gray, siliceous orthoquartzites occur in the middle and upper portions of the Ridgeley Member.

In the northern portion of the map area, the Ridgeley largely contains calcite-cemented orthoquartzites, whereas in the southern portion of the map area, the Ridgeley largely contains silica-cemented orthoquartzites. The ferruginous-cemented orthoquartzites of the Ridgeley Member are limited to the southern half of the map area.

The Ridgeley Member is exposed in the cut for the Pennsylvania Turnpike at Everett. A description of exposure is presented graphically in Figure 7 and the detailed description is included in the Appendix.

The ferruginous- and the siliceous-cemented orthoquartzites were studied in thin section. No indurated samples of the calcareous-cemented orthoquartzites were found.

The siliceous-cemented orthoquartzite is a moderately well-sorted, medium sand, composed of quartz, in part consisting of vein quartz and vermiculated quartz, chert, and some metaquartzite rock fragments. The well- rounded quartz grains show a normal, wavy, or patchy extinction. In some grains, the areas of patchy extinction are outlined by bubble trains or thin crushed zones. Silica overgrowths have reduced roundness and produced an interlocking mosaic of quartz.

The ferruginous-cemented orthoquartzites are coarse grained and more poorly sorted than the siliceous-cemented orthoquartzites. The ferruginous orthoquartzites consist of a moderately sorted, medium- to very coarse-grained sand composed of quartz, chert, and metaquartzite rock fragments. The sand consists of a mixture of subangular grains and rounded, commonly fractured grains. The subangular grains appear to have been derived from the break-up of the rounded grains. The ferruginous cement, which represents 20 to 30 percent of the rock occurs as well-formed crystals of hematite coating pore spaces and filling fractures within the grains. These relationships suggest that the iron was introduced into the sandstone after deposition. Silica overgrowths preceded the cementation by iron.

The identified fauna of the Ridgeley Member includes *Costipirifer arenosus, Meristella* sp., *Acrospirifer murchisoni,* and *Acrospirifer intermedius.* The Ridgeley is correlated with the Oriskany Sandstone of New York (Cleaves, 1939, p. 116).

Onondaga Formation

The Onondaga Formation (Hall, 1839) crops out as a narrow, continuous band paralleling the eastern margin of the map area. East of Eichelbergertown the Onondaga Formation is about 77 feet thick.

The contact of the Onondaga with the Ridgeley member of the Old Port Formation is marked by a distinct break in slope. The upper contact is marked by a change from the greenish-gray shaly limestone of the Onondaga Formation to the black shales of the Marcellus Formation. Exposure of the formation is poor.

The Onondaga Formation is composed of dark-gray and greenish, calcareous and noncalcareous shales interstratified with layers of thin-bedded, dark-gray, pure to argillaceous limestones. The formation generally weathers soft and crumbly with an olive gray or brownish gray color. At the base, the dark-gray noncalcareous shales of the Onondaga Formation are in sharp contact with the orthoquartzites of the Ridgeley. The top of the Onondaga Formation which is in sharp contact with the overlying Marcellus Formation is marked by a brownish-gray calcareous silty shale.

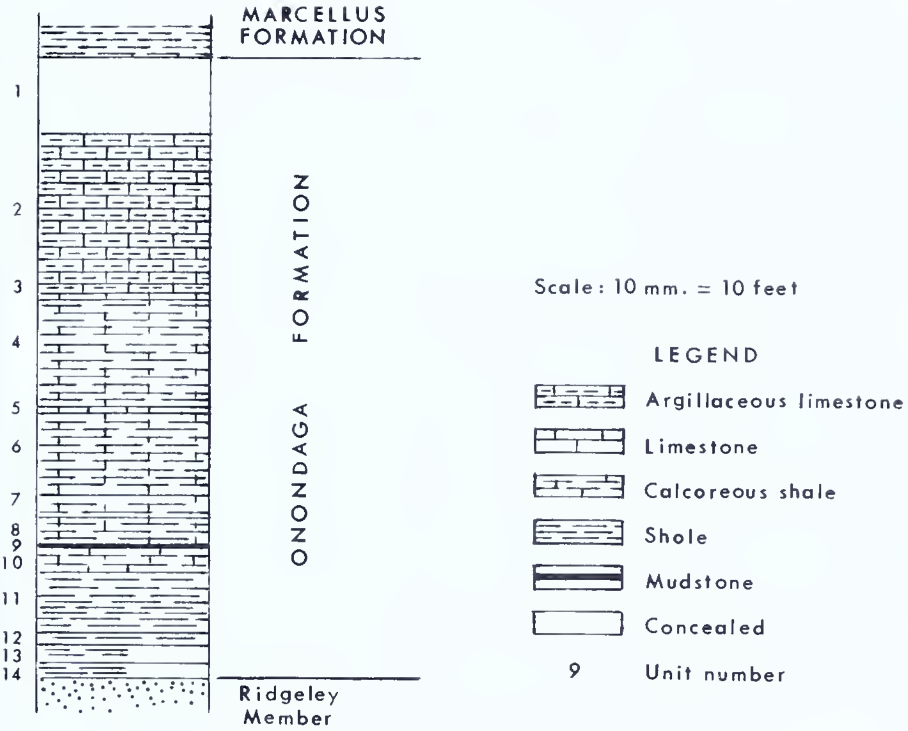


Figure 8. Detoiled columnor section of the Onondoga Formation exposed near Eichelbergertown.

About one mile north of Eichelbergertown the Onondaga Formation is fully exposed along an old farm road on the north side of the creek that cuts through the Ridgeley sandstone ridge at this point. A description of this section is presented graphically in Figure 8. The detailed description is included in the Appendix.

The only fossil found in the Onondaga Formation is the brachiopod *Orbiculoidea lodiensis var. media* (?). Willard (1939, p. 155) assigns to the Onondaga a Middle Devonian age and correlates it with the Buttermilk Falls and the Esopus of eastern Pennsylvania.

Marcellus Formation

The Marcellus (Hall, 1839) parallels the distribution of the Onondaga Formation and occurs as a narrow, continuous band along the eastern margin of the map area.

The exposure of the Marcellus Formation is marked by a zone of black shale fragments between the olive shales of the overlying Mahantango Formation and the olive-gray and brownish-gray shales of the underlying Onondaga Formation. East of Eichelbergertown the Marcellus is 217 feet thick.

The Marcellus black shale is predominantly jet-black, noncalcareous, fissile, paper-thin, carbonaceous shale which weathers to soft and crumbly, grayish-black, whitish-edged fragments. Near the base, several layers of dusky-brown, paper-thin shales interbed with the jet-black shales. At the base, black shales of the Marcellus rest in sharp contact with the brownish-gray calcareous shales of the Onondaga. At the top, the black shales of the Marcellus Formation are in sharp contact with the greenish-gray and dark-gray shales of the lower Mahantango Formation.

No fossils were found in the Marcellus. The Marcellus black shale is Middle Devonian in age (Willard, 1939, p. 161).

Mahantango Formation

The Mahantango Formation (Willard, 1935) crops out as a continuous, northeastward-trending band along the eastern boundary of the map area. The lower portion of the Mahantango Formation forms a rolling, grass-covered surface at about the same elevation as the surface developed on the Marcellus and Onondaga Formations. The upper portion of the Mahantango Formations forms a series of tree-covered, semi-continuous ridges standing about 50 to 100 feet above the general level of the valley. West of Saxton, Pennsylvania, the Mahantango Formation is 1075 feet thick.

The lower contact of the Mahantango Formation was drawn at the change from the dark-gray and olive-gray shales of the Mahantango Formation to the jet-black shales of the Marcellus. The contact of the Mahantango Formation with the overlying Harrell Formation is marked by a narrow subsequent valley.

The Mahantango may be divided into three members: a lower shale member, a ridge-forming middle sandstone member, and an upper shale member. The lower shale member consists of an alternating sequence of brownish-weathering, dark-gray, olive-gray, and greenish-gray shales and silty shales with thin interbeds of fine-grained, laminated and cross-laminated sandstones. The sandstones, which near the base represent from 5 to 10 percent of the member, become thicker and more numerous towards the top, so that the lower shale member grades into the middle sandstone member. The middle sandstone member contains several 25- to 40-foot-thick layers of thin-bedded, dark-gray and olive-gray, fine-grained sandstone, separated by thick layers of olive, dark-gray, and brownish-gray shales and silty shales. The upper member is composed of dark-gray and olive-gray shales with several interbeds of 15- to 20-foot-thick layers of dark-gray, thin-bedded, partially cross-laminated siltstones. At the base, the greenish-gray and dark-gray shales of the Mahantango Formation rest in sharp contact on the jet-black shales of the Marcellus Formation. The upper contact with the Harrell Formation is concealed, but apparently the Tully Member of the Harrell is absent or very thin. A few argillaceous limestone nodules were observed

0.7 miles east of Tatesville at the top of the Mahantango. These may represent the Tully Member of the Harrell Formation.

In material collected from the Mahantango Formation, the writer identified *Tropidoleptus carinatus, Mucrospirifer mucronatus, Rhipidomella* sp., and *Chonetes marylandica*. The fauna indicates a Middle Devonian age for the Mahantango Formation.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The structural grain of the map area trends about North 20° East. The major structures of the map area (Figure 9) are the Friends Cove anticline, the Warrior Ridge anticline, the Yellow Creek syncline, the Friends Cove fault, and the East and West Henrietta faults. Minor structural features includes intense folding in the Yellow Creek syncline and local folding of the Keyser-Ridgeley sequence.

MAJOR FOLDS

Friends Cove Anticline

The Friends Cove anticline is a broad, 20-mile-long, plunging, asymmetrical to overturned anticline, whose axial trace trends about North 25° East. The northern end of this fold is exposed in the Everett quadrangle. Near the southern boundary of the quadrangle, the axial trace of the anticline is truncated by the Friends Cove fault (Figure 9). The eastern limb of the Friends Cove anticline dips 30 to 50 degrees to the southeast. At Bedford Narrows the western limb of the anticline is overturned and dips 76 to 86 degrees to the east. Northward, this limb passes through vertical and assumes a dip of 40 to 80 degrees to the west. The fold plunges 4 to 10 degrees to the north.

Warrior Ridge Anticline

The Warrior Ridge anticline is in the northeastern portion of the map area (Figure 9). This fold is a southwestward-plunging, long, narrow, slightly asymmetrical anticline with a curving axial trace. The trend of the fold is North 10° East, but at the southern end the axial trace curves westward so that the fold plunges in a South 30° West direction. At the northern end of the fold the axial trace is truncated by the East Henrietta fault. The outcrop pattern of the Juniata-Bald Eagle sandstone indicates that the fold contains a saddle along the crest. The east limb dips 40 to 60 degrees to the east and the west limb dips 30 to 50 degrees to the west. The fold plunges gently south at about 10 to 15 degrees.

Yellow Creek Syncline

The Yellow Creek syncline is in the central portion of the map area and is named after Yellow Creek, a small village on the east limb of the structure. The fold is a doubly plunging, slightly asymmetrical syncline occupying the structural low between the Warrior Ridge anticline on the east and the Morrison Cove anticline on the west. From north to south the axial trace trends North 20° East, curves to a North 15° West direction, and then returns to its original trend (Figure 9). The deflection in the axial trace reflects the plunging out of the Friends Cove anticline, the nose of which forms a part of the southwestern flank of the syncline. At the center of the fold the axial trace is located by a series of doubly plunging en echelon folds in the Wills Creek-Tonoloway sequence (Figure 9). At the northern end the syncline plunges about 6 to 8 degrees to the south, and at the southern end it plunges about 1 to 3 degrees to the north.

MAJOR FAULTS

Friends Cove Fault and Everett Gap Fault

The Friends Cove fault is a large thrust fault on the western flank of the Friends Cove anticline. The northern end of the fault is exposed in Snake Spring Valley. The trace of the fault extends North 35° East for a distance of about 2½ miles. This fault trace then appears to turn to a South 65° East direction and continues as the Everett Gap fault, which is the name here given to the right lateral transverse fault which crosses Snake Spring Valley and extends into Everett Gap (Figure 9). In the gap, the Everett Gap fault turns to a North 70° East direction and continues beyond the mapped area. The Friends Cove fault may have originally continued north of the Everett Gap fault.

The Friends Cove fault has thrust the Warrior Formation westward into contact with the Bellefonte Dolomite. Southward, the Warrior Formation is in fault contact with progressively younger beds, indicating that the heave increases in that direction. The displacement on the Friends Cove fault cannot be determined because the dip of the fault plane is not known. The straightness of the fault plane suggests a relatively high angle. At a maximum the fault has cut out about 4000 feet of section. The continuation of the Friends Cove fault north of the Everett Gap fault (Figure 9) has cut out only about 1000 feet of section.

A second, smaller thrust fault crops out west of the Friends Cove fault (Figure 9). The trace of the faults trends North 30° East in a broad arcuate pattern about 2 miles long. The dip of the fault plane is not known, but its straight trace suggests that it also is probably a high angle fault. Locally, this thrust has cut out about 500 feet of Middle Ordovician limestones.

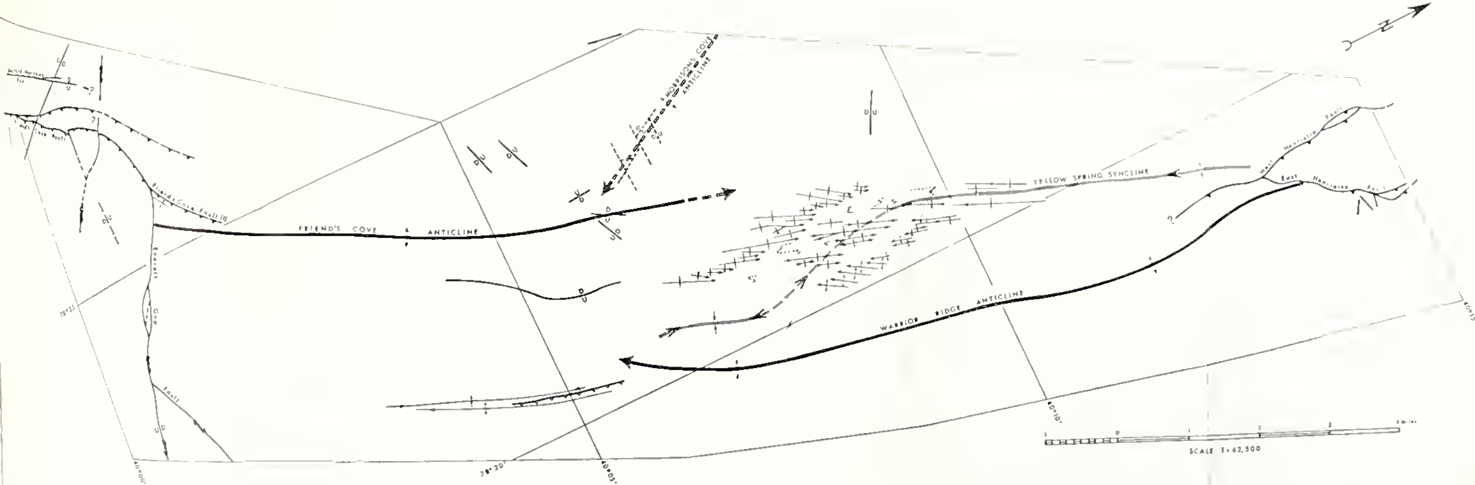


Figure 9. Structural elements of the mapped area

Two faults are present at the eastern mapped extremity of the Everett Gap fault (Figure 9). One is the main Everett Gap transverse fault with right lateral movement. A second fault, south of Everett Gap fault, but intersecting it, may be a high angle fault with the south wall up relative to the north wall to produce the apparent lateral offset in the eastward-dipping rocks. The presence along the main Everett Gap transverse fault zone of two vertically dipping slices of the Benner, Hatter, and Loysburg Formations indicates that the main Everett Gap fault may have a vertical component of movement.

The first-formed fault in the Friends Cove anticline group is the smaller fault immediately west of the Friends Cove fault. The Friends Cove fault truncates this fault at the southern end of the map area. The smaller fault apparently began as an eastward-dipping thrust fault striking diagonally from the Reedsville Formation to the Bellefonte Formation. Later movement thrust the Bellefonte into contact with the Reedsville Formation.

The Friends Cove fault began after the smaller thrust to the west and may have originally roughly paralleled it. After initiation of the Friends Cove fault, the Everett Gap fault formed. It is suggested that continued movement along the Friends Cove fault was partly taken up by lateral movement along the Everett Gap fault. This conclusion is supported by the 4000 feet of missing section along the Friends Cove fault south of the Everett Gap fault as compared to only 1000 feet of missing section north of the Everett Gap fault.

Within Everett Gap the southern high angle fault may reflect a part of the upward movement of the south side of the transverse fault resulting from thrusting on the Friends Cove fault.

East and West Henrietta Faults

The East and West Henrietta faults were first mapped by Butts (1945) in the Hollidaysburg quadrangle. The two faults bound a lens-shaped block about 6 miles long and 1 mile wide containing eastward-dipping Lower Ordovician to Lower Cambrian strata. The faults trend north-south in the Hollidaysburg quadrangle and cut diagonally across the North 20° East trend of the regional fold structure.

The southern end of these two faults is exposed in the area covered by this report. The East Henrietta fault changes from a north-south trend to South 40° West and joins the West Henrietta fault in an area covered by talus. The combined faults continue southward as a large fault parallel to the west limb of the Warrior Ridge anticline. The West Henrietta fault has placed the Upper Cambrian Gatesburg Formation in contact with the Upper Ordovician and Lower Silurian Bald Eagle to

Tuscarora sequence, and the East Henrietta fault has placed Lower Ordovician Nittany in contact with the Reedsville to Juniata sequence.

Recent mapping by D. M. Hoskins in the area of the Henrietta faults shows that the East Henrietta fault at its easternmost extremity includes a wedge of the Juniata Formation faulted against the Bald Eagle and Juniata Formation. The West Henrietta fault included two small wedges of the Bald Eagle Formation along its trace. The rock exposed in the southern of these two wedges is brecciated.

The trace of the southern part of the Henrietta fault was determined by Hoskins by outcrops and float crops of brecciated Tuscarora quartzite. Just north of the mapped southern end of the fault the trace swings westward onto the top of the west flank of Warrior Ridge. There the Juniata Formation occupies the ridge crest and the Tuscarora is exposed on the west flank of the ridge. About 300 feet of Tuscarora are cut out by the fault here. The fault cannot be traced with certainty south of the point where the Tuscarora occupies the ridge crest and a normal stratigraphic thickness is present. South of this point the fault lies entirely within the Juniata Formation and appears to stop.

At the extreme northern edge of the Everett quadrangle the Cambrian Gatesburg Formation and Ordovician Bald Eagle Formation are in contact. Here the trace of the fault as mapped by Hoskins from the lowlands underlain by carbonates to the high ridge held up by the resistant Bald Eagle sandstones indicates a steeply east-dipping fault plane.

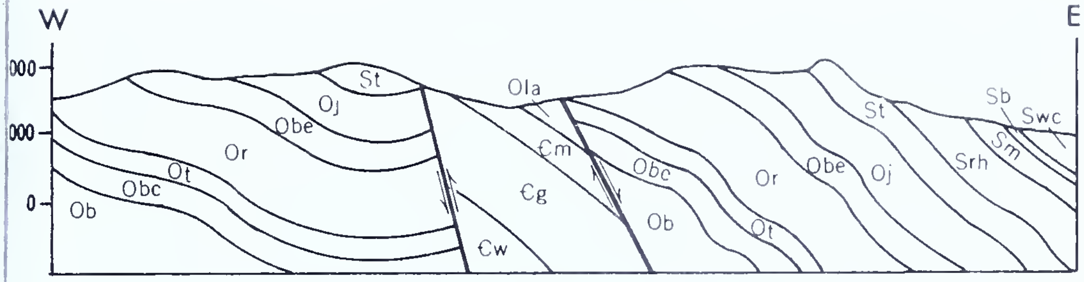
The generally straight trace of both the East and West Henrietta faults in the Everett quadrangle and in the Huntingdon quadrangle immediately to the north indicates that the faults dip relatively steeply, most likely to the east.

The writer has been unable to determine the nature of the Henrietta faults and therefore offers three structural interpretations as working hypotheses to explain the map pattern.

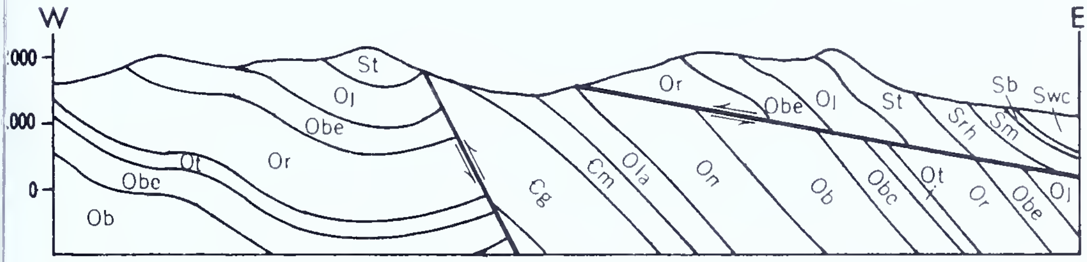
Hypothesis I—The East and West Henrietta faults are both eastward-dipping, high angle faults which bound a horst (Figure 10a). This is the interpretation used by Butts (1945).

The stratigraphic offset on the West Henrietta fault is about 5000 feet, and that on the East Henrietta fault about 3000 feet. Butts (1945, p. 15) noted that the East Henrietta fault appears to have thrust younger beds on top of older beds and concluded that the fault-bound block must be a wedge-shaped slice emplaced by a push from below. This interpretation, however, does not explain the slice containing the Juniata Formation adjacent to the East Henrietta fault.

Hypothesis II—The map pattern is the result of low angle thrust faulting on the East Henrietta fault and high angle thrust faulting on



a. Hypothesis I. Horst



b. Hypothesis II. High-angle thrusting followed by low-angle thrusting.

Figure 10. Geologic cross sections showing structural interpretations of the East and West Henrietta faults.

the West Henrietta fault (Figure 10b). Both faults dip to the east. High angle reverse faulting on the West Henrietta fault would thrust the core of the Warrior Ridge anticline onto the east flank of the adjacent syncline. Low angle reverse faulting on the East Henrietta fault would shear off the top of the Warrior Ridge anticline and move the east flank westward into contact with the older beds at the core of the fold. Subsequent erosion could produce the present map pattern. The main objection to this hypothesis is that the straightness of the trace of the East Henrietta fault in the Hollidaysburg quadrangle (Butts, 1945) suggests that it is a high angle fault. However, in the area covered by this report, the trace of the southern extension of the East Henrietta fault shows a pattern suggestive of an eastward-dipping, low angle fault.

Hypothesis III—A third hypothesis is presented in Geologic Cross Section A-A′ (Plate I). In this interpretation the East and West Henrietta faults are subparallel faults dipping eastward at a moderate angle.

The map pattern in the northern part of the area may be explained by more than one hypothesis, but uncertainty as to the dip and direction of movement on the fault planes makes the selection of the correct interpretation impossible.

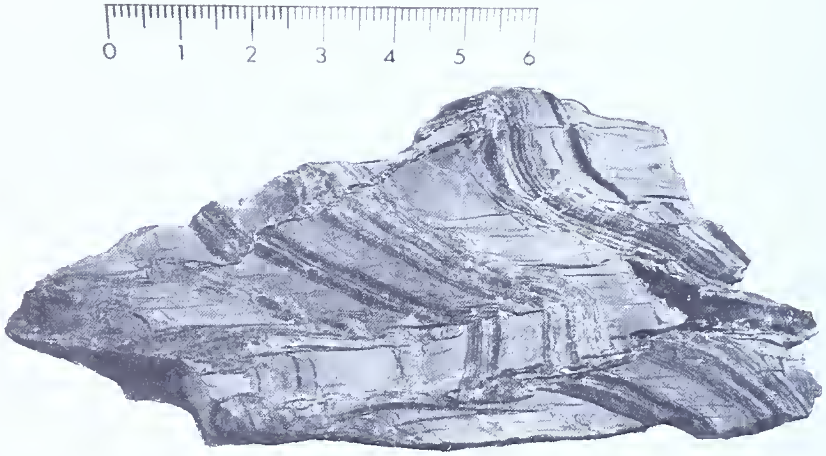


Figure 11. Hand specimen of micro-fold in Wills Creek Formation. Light-colored bands are argillaceous limestone; dark bands are purer limestone. Curve in uncleaved limb and hinge (lower right) indicates that concentric folding preceded cleavage folding. Fracture cleavage produces small offsets in argillaceous bands. General cleavage cuts across all bands. Scale in millimeters.

MINOR STRUCTURES

Intricate folding in the Yellow Creek syncline

On the northern and southern flanks of the Yellow Creek syncline (Figure 9), the Bloomsburg Formation crops out in a zig-zag pattern reflecting local en-echelon folds plunging toward the axis of the syncline. The wave length and amplitude of the en-echelon folds differ on the northern and southern flanks on the Yellow Creek syncline and reflect a difference in degree of folding and thickness of the Bloomsburg. On the northern flank the Bloomsburg is about 65 feet thick and folds have a half-wave length of 375 to 450 feet, whereas on the southern flank the Bloomsburg is about 40 feet thick and the folds have a half-wave length of 300 to 375 feet. De Sitter (1956, p. 189) has argued that the thickness of a competent layer and the amount of shortening determine the size of a fold.

More open folds shown by tracing the Rabble Run Member of the Mifflintown Formation indicate that the folds in the overlying Bloomsburg die out rapidly with depth. This may indicate that the Bloomsburg is acting as a local strut member, and that the underlying beds are folded parallel to the Bloomsburg.

The Wills Creek and Tonoloway Formations constitute a very incompetent section of beds which have been intricately folded into sharply plunging anticlines and synclines at the center of the Yellow Creek syncline. The intense character of this folding is shown in aerial photographs of farmed areas in the Wills Creek Formation and by the doubly plunging synclinoria developed into the Tonoloway Formation. The steep plunge of these folds indicates that they are of the cleavage type (De Sitter, 1956). The extent of this folding can be illustrated in a hand specimen of the Wills Creek (Figure 11). The specimen shows the hinge and limb of a micro-fold containing light-colored bands of argillaceous limestone and dark-colored, thin bands of pure limestone. The bending in some of the pure limestone bands on the limb and the curved but uncleaved hinge suggest that folding began as the concentric type. A fracture cleavage then developed in the argillaceous bands sub-parallel to the fold axis. Movement along the microlithons produced small offsets in the limb. Subsequently some of the cleavage planes extended themselves to become a general cleavage. Additional movements subparallel to the fold axis have taken place on this general cleavage.

In general, the fold axes in the Bloomsburg, Wills Creek, and Tonoloway Formations strike diagonally to the axis of the Yellow Creek syncline, but are parallel to the fold axis of the Warrior Ridge anticline (Figure 9). Folding along the hinge of the Yellow Creek syncline indicates that these folds are not drag folds, but the response of relatively incompetent strata being squeezed between the rising Warrior Ridge anticline on the east and the Morrison Cove anticline on the west.

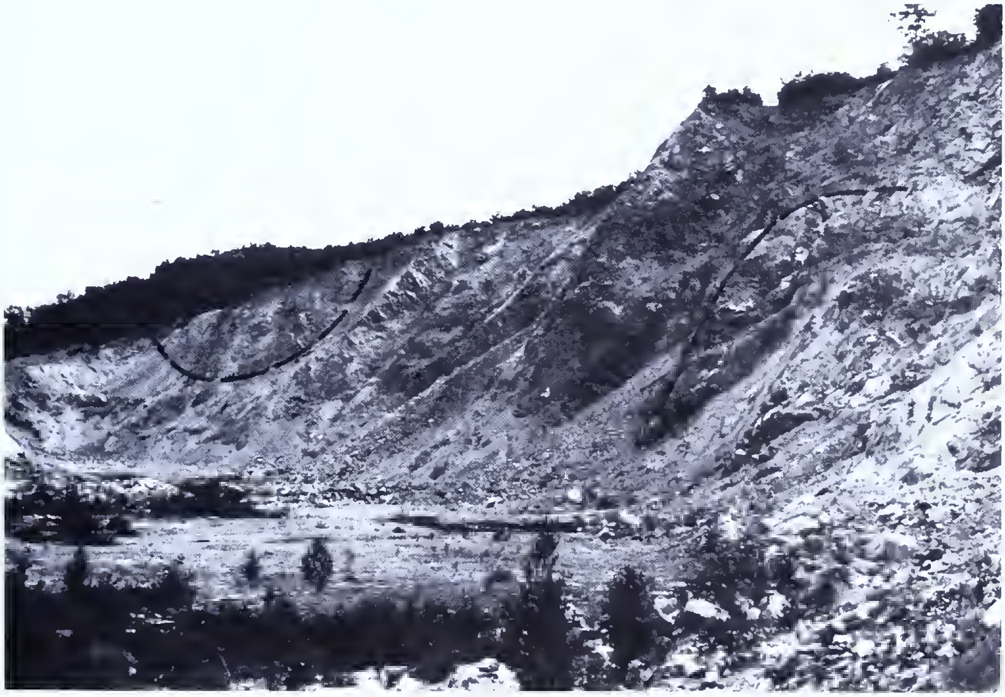


Figure 12. Folds exposed in quarry in Ridgeley sandstone at Tatesville. Note synclinal and anticlinal folds exposed in quarry wall. View is northward parallel to fold axes. Quarry face in foreground is about 100 feet high. Dashed lines emphasize bedding.

Folding and Faulting of the Ridgeley Member

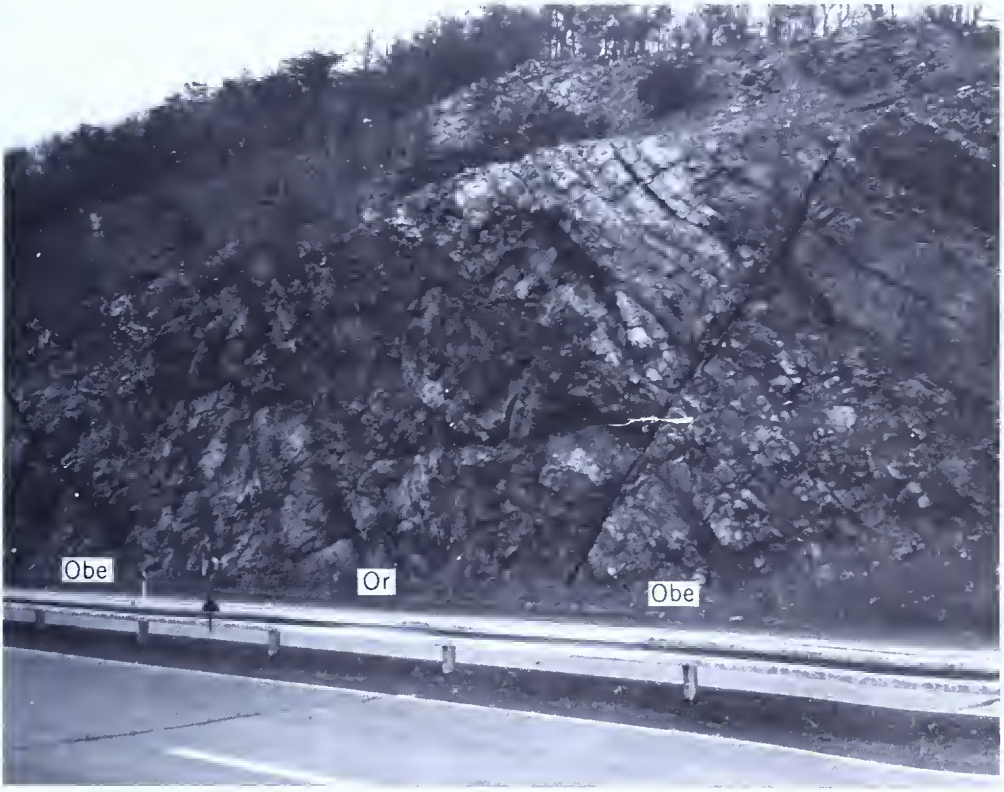
In the quarry at Tatesville the sandstones of the Ridgeley Member are folded into an anticline and syncline (Figure 12) whose axial trace trends North 20° East and plunges 2 to 4 degrees south. These folds extend for nearly three miles to the north where the map pattern indicates that the Keyser and Old Port Formations have been folded as a single unit. These folds are not the southern continuation of the Warrior Ridge anticline, the axis of which lies to the west, but rather represent a drag fold on the flank of that anticline. A longitudinal fault at the northern end of the Ridgeley syncline (cross section E-E′) has thrust the core of the small anticline immediately to the east onto the flank of the Ridgeley syncline to the west. This thrusting may be due to insufficient room at the core of the anticline to accommodate the folding strata. The drag folding affected the underlying upper Tonoloway Formation but did not affect the still older Wills Creek Formation. The Keyser and Old Port Formations acted as a strut member which upon folding caused the enclosing incompetent beds to form parallel folds.

Overturned Thrust Faults

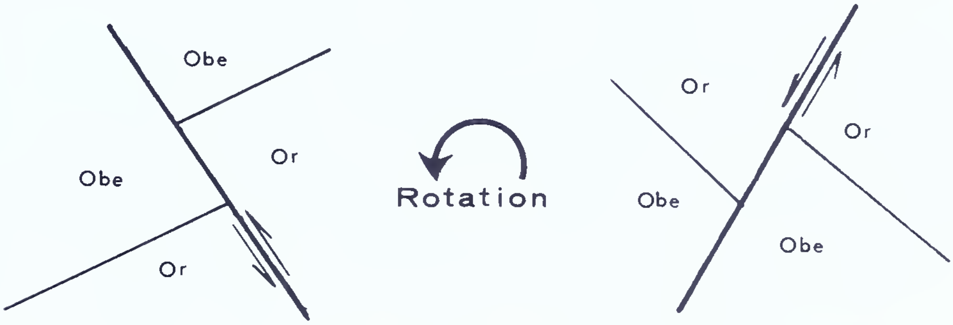
The overturned Bald Eagle-Reedsville section exposed on the Pennsylvania Turnpike at Bedford Narrows has been thickened by faulting. The section contains several vertical or west-dipping high angle faults in which the slickensides indicate latest movement opposite to that required by the stratigraphic offset. The faults are interpreted as reverse faults formed by westward thrusting when the beds were right side up; they have been subsequently overturned to their present position.

The first such fault (Figure 13) is located at the east end of the road cut. The Reedsville Formation occurs on top of the Bald Eagle Formation and the beds strike North 50° East and dip 60° Southeast (overturned). The fault strikes North 50° East, dips 62° West, and the slickensides indicate that it is a normal fault.

The second fault (Figure 14) is about 200 feet to the west of the first-mentioned fault and is similar except that two slices of the Bald Eagle Formation has been incorporated into the fault and thrust along with the Reedsville Formation. On the left, the Reedsville strikes North 28° East, dips 75° East (overturned) and is in depositional contact with the underlying Bald Eagle sandstone. At the center, two wedge-shaped blocks of Bald Eagle sandstone are in fault contact with crumpled beds of Bald Eagle on the east and with Reedsville shale on the west. The fault on the west side strikes North 30° East and dips 85° Southeast. The fault on the east side strikes North 35° East and dips 80° West. To the right of the photograph the Bald Eagle strikes North 32° East and dips 47° East (overturned). When the beds are rotated (Figure 14b) to a right-side-up position, these two faults become eastward-dipping reverse faults that have thrust the Reedsville and a slice of the Bald Eagle sandstone into fault contact with the Bald Eagle. The diagonal fault on the fault slice is a reverse fault striking North 35° East and dipping



a. View toward north showing faulted (dashed line) and overturned Bald Eagle (Obe) and Reedsville (Or) strata. Movement on fault determined by slickensides. Arrow indicates man for scale.

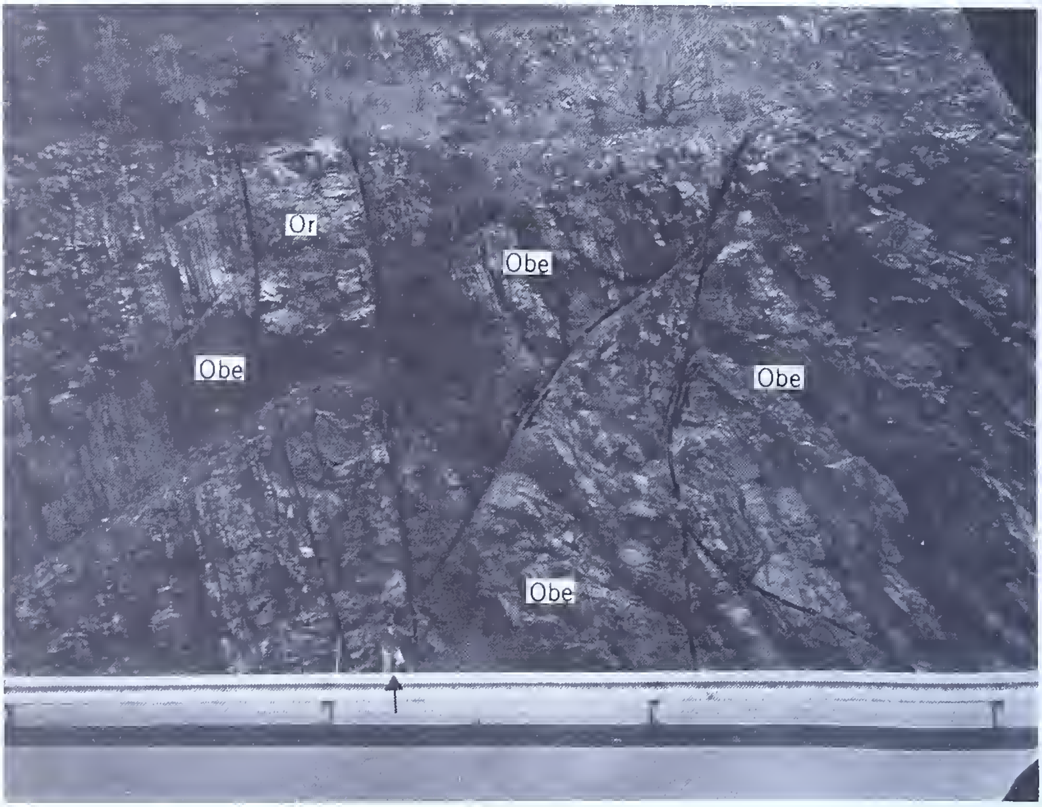


b. Thrust fault formed when strata were right side up.
Beds overturned to present attitude.

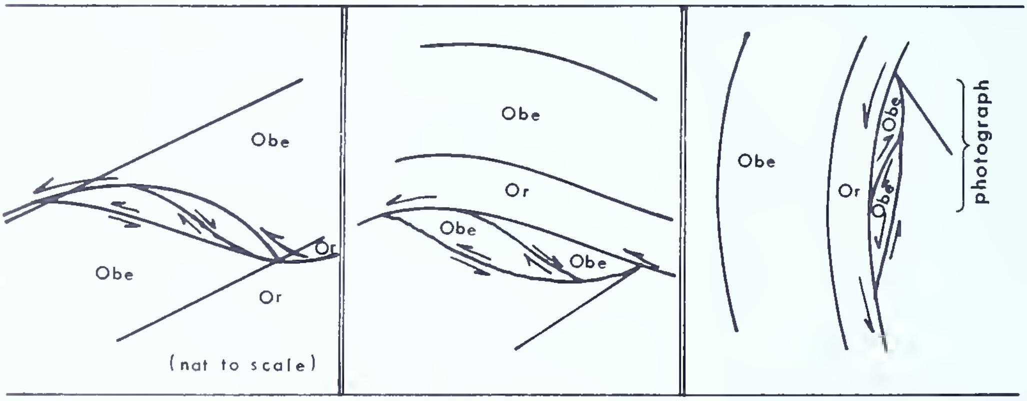
Figure 13. Fault exposed at east end of Pennsylvania Turnpike cut at Bedford Narrows.

55° West. When rotated back to the right-side-up position (Figure 14b), it becomes a normal fault caused by the shearing out of the fault slice.

The faulted zone has been traced by D. M. Hoskins south subparallel to the regional strike for a distance of about two miles. The Bald Eagle,



a. Section of much faulted (dashed lines), crumpled, and overturned Bald Eagle (Obe) and Reedsville (Or) strata. Movement on faults determined by slickensides or stratigraphic offset. Crumpled beds at right are overturned drag folds. Reedsville shale about 10 feet thick. Arrow indicates man for scale.



b. Thrust faults form, strata right side up. *Thrusting* *Beds overturned to present attitude*

Figure 14. Faults exposed in Pennsylvania Turnpike cut at Bedford Narrows.

Juniata and Tuscarora Formations are offset in turn. About one mile south of the southern edge of the Everett quadrangle the fault zone is at the top of Evitts Mountain. The lower part is not offset; thus the fault apparently passes into bedding plane movement within the Tuscarora Formation. To the north of Bedford Narrows the fault zone is traceable only into the Reedsville Formation. It apparently does not affect older formations and thus probably passes into bedding plane movement within the Reedsville.

High Angle Transverse Faults

These faults cut and offset competent Upper Ordovician and Silurian sandstone layers but die out in the adjacent incompetent shaly layers. Included in this group are the peri-anticlinal faults. (De Sitter. 1956, p. 208) at the nose and central part of the Friends Cove anticline. Their orientations with relation to the fold axis indicate that they are of either shear or tensional origin. These faults have formed as a result of the local stretching or shearing of the rocks as they were folded.

The largest of these faults has an apparent maximum lateral movement of 400 feet. This fault is readily apparent where it crosses the west flank of Friends Cove anticline about 1 mile north of Bedford Narrows.

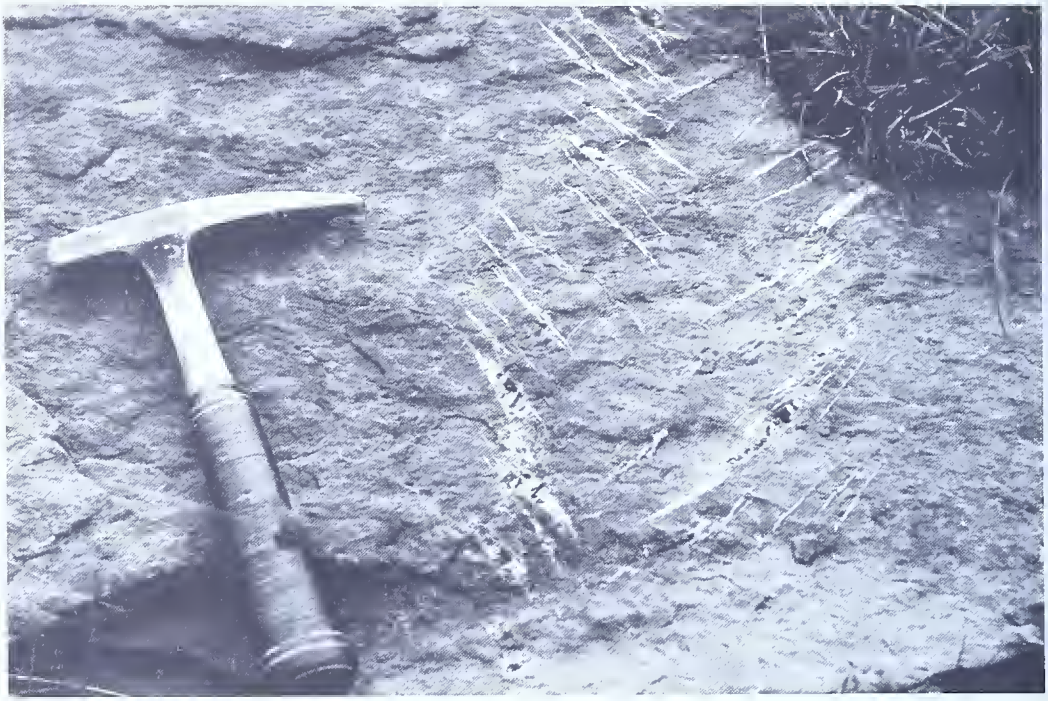
High Angle Reverse Fault

A high angle fault traceable for about two miles is present on Tussey Mountain near the nose of Friends Cove anticline. This fault is similar to the west-dipping "normal" fault exposed in Bedford Narrows in that it apparently offsets only the competent Bald Eagle to Tuscarora sequence. The movement on this fault, however, as determined from the areal relationships, is that of a reverse fault.

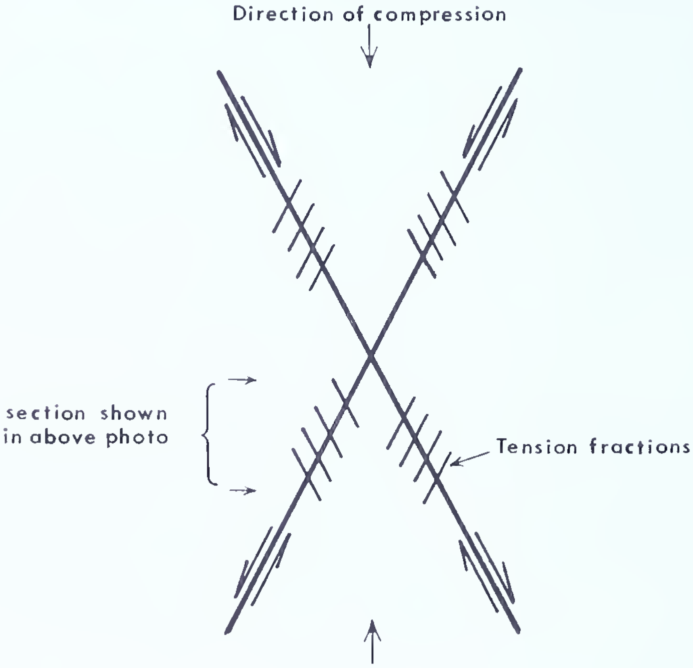
En Echelon Tension Fractures

About a fifth of a mile northwest of the Smith Elementary School, Yellow Creek, the western flank of a southward-plunging anticline in the Bloomsburg Formation contains two sets of en echelon tension fractures (Figure 15a). The fractures are 2 to 4 inches long, 1/16 to 1/4 inch wide and partially to completely filled with quartz. Lines drawn through the two rows of en echelon fractures form a conjugate set with an acute angle of about 30 degrees. The acute bisectrix is oriented at about 90 degrees to the axis of the anticlines.

Shainin (1950) has described similar fractures in the Athens limestone of Virginia. According to Shainin, the en echelon arrangement of the tension fractures indicates a force couple acting parallel to the trend of the row (Figure 15b). The conjugate set formed by the two rows indi-



a. En echelon tension fractures; the two rows form a conjugate set.



b. Force couples acting parallel to conjugate shear directions to produce en echelon tension fractures. After Shainin (1950).

Figure 15. En echelon tension fractures in Bloomsburg siltstone.

cates that these are shear directions and that "each row may be considered as the trace of a plane of incipient shearing" (Shainin, 1950, p. 509).

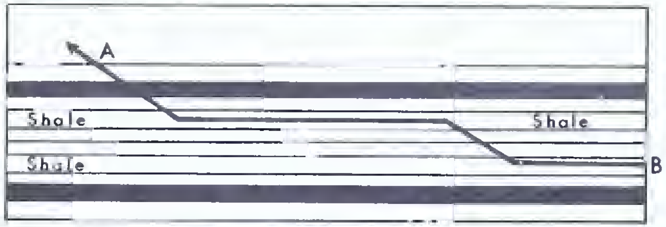
The following hypothesis is offered to explain why conjugate sets of en echelon tension fractures form in some cases and conjugate shears in others. A rock under tension will fail at a lower stress than that required to produce failure when the rock is under compression (Hill, 1963, p. 105). En echelon tension fractures may form as a result of the slow buildup of a shearing couple which does not exceed the shearing strength of the rock but has exceeded its tensile strength. A shear fracture would appear to form under greater stress and high stress acceleration. In the development of a shear fracture the stress being applied builds up rapidly and quickly exceeds the point at which tension fractures would form.

MECHANICS OF FOLDING

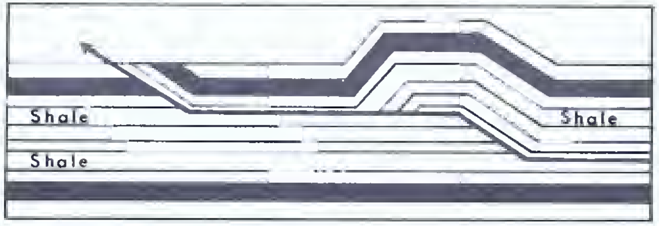
Gwinn (1964) has proposed that the mechanics of low angle overthrust faulting used by Rich (1934) to explain the Cumberland thrust block is generally applicable to the Ridge and Valley province. Recent exploratory drilling by several oil companies [Kerr McGee No. 1 Martin (1963 Guidebook, Pittsburgh Geological Society) and Socony Mobil No. 1 Franklin Long (Robert Harting, oral communication)] in the Folded Appalachians of Pennsylvania appears to confirm Gwinn's proposal.

Figures 16a and 16b are taken from Rich (1934, p. 1589) to illustrate the mechanics of low angle overthrust faulting. Rich stated that when a compressive stress is applied to an interbedded sequence of competent and incompetent strata, bedding plane thrusts develop in the incompetent layers. The thrust plane follows a zone of easy gliding such as the lower shale in Figure 16a, and then breaks diagonally upward across the more competent strata to a higher zone of easy gliding and follows that horizon. As a result of the displacement of the block above the fault plane, an anticline (Figure 16b) will form where the thrust breaks upward from a lower to a higher glide plane. The size of the anticline depends upon the thickness of the competent layer between the two glide planes and upon the amount of thrusting that takes place. The mechanism produces flat-bottomed synclines and, depending upon the amount of thrusting, round-crested to broad-topped anticlines. The bedding plane thrusts occur, according to Rich, in incompetent units such as shales, calcareous shales, and thin-bedded limestones. Thrusting on the diagonal fault planes brings to the surface the beds from the lower glide zone and allows us to identify the glide horizons.

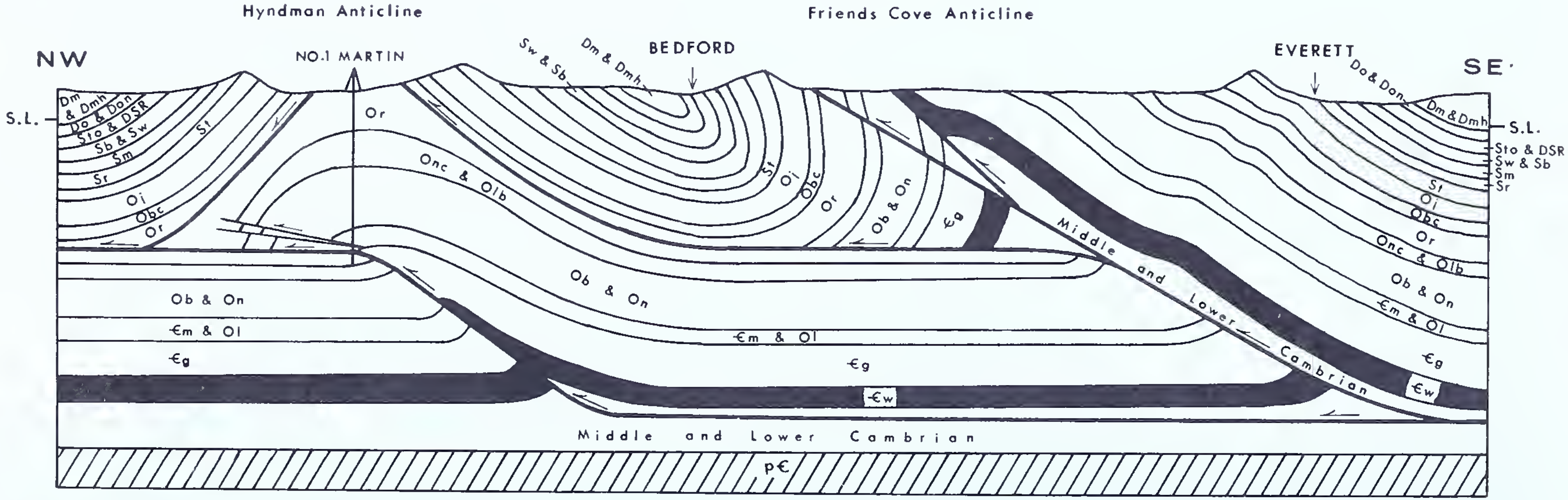
Figure 16c is an east-west geologic cross section of the Hyndman and Friends Cove anticlines. The figure is a composite cross section con-



a. Diagram representing course of incipient thrust plane (A-B) in series of sedimentary rocks. After Rich (1934).



b. Diagram showing result of movement on thrust fault such as that in Figure a. After Rich (1934).



c. Geologic section across Hyndman and Friends Cove anticlines. Structural interpretation drawn according to principles illustrated in diagrams a and b above. Note that Pre-cambrian rocks are not involved in the folding. Explanation of symbols is on Plate 1.

Figure 16. Cross sections illustrating overthrust faulting.

structed by projecting the subsurface data of the No. 1 Martin well and the surface data of the Friends Cove anticline onto a single plane.

The Friends Cove and Hyndman anticlines are interpreted to have a similar origin; a bedding plane thrust in the Lower Cambrian Waynesboro Formation may have sheared diagonally across the Middle Cambrian-Middle Ordovician carbonates to the Reedsville Shale. The Hyndman anticline is a narrow, round-crested anticline formed as a result of a relatively small displacement on the thrust plane. The Friends Cove anticline is a further stage of development of this type of fault-related anticline. In the case of the Friends Cove anticline the displacement of the thrust plane has been larger than in the case of the Hyndman anticline, and the resulting fold is therefore wider and broad topped. Subsequent high angle reverse faulting, as a splay off the diagonal fault plane (Figure 16c), has thrust the core of the Friends Cove anticline onto its own western flank.

This interpretation is supported by data from Butts's (1945) work in the Hollidaysburg quadrangle which indicates that the upper portion of the Lower Cambrian Waynesboro Formation may be a glide zone. Southwest of Bedford, the Kerr-McGee No. 1 Martin well encountered the Reedsville Formation at a depth of 6174 feet after drilling through a normal Middle and Lower Ordovician section. These depths indicate that the Reedsville shale forms the next higher glide zone above the Waynesboro Formation. At Jacksonville, Pennsylvania, the Socony Mobil No. 1 J. Franklin Long well encountered flat-lying Rose Hill and Tuscarora at a depth of about 7000 feet after drilling through a much-faulted Beekmantown to Gatesburg sequence. The Rose Hill thus appears to form the next higher glide zone above the Reedsville. Thus, in the Cambrian-Silurian sequence there are three glide horizons: the Waynesboro Formation, the Reedsville Formation, and the Rose Hill Formation.

The structural relief on the Friends Cove anticline is on the order of 10,000 feet, and on the Hyndman anticline on the order of 6,000 feet. These two anticlines appear to be the result of a westward displacement of about three miles of the allochtonous block above the Waynesboro-Reedsville thrust plane (Figure 16c).

The major anticlines in the map area, the Friends Cove and Warrior Ridge anticlines, thus are interpreted to be fault-related anticlines formed as a result of a bedding plane thrust crossing diagonally upward to the next higher level of gliding. The developing anticlines would set up a stress in the adjacent synclines which would squeeze the overlying incompetent strata to produce local intricate folding similar to that actually found in the Yellow Creek syncline.

As the Warrior Ridge anticline grew, there would have been a movement of the strata from adjacent synclines toward the crest of the anticline. This movement would induce a force couple on the flanks of the anticline and drag folds of the type found in the Keyser-Ridgeley sequence could result. The growing Warrior Ridge and Friends Cove anticlines would stretch and shear the overlying competent strata and result in high angle faults developing at the same time as the folds are increasing in size.

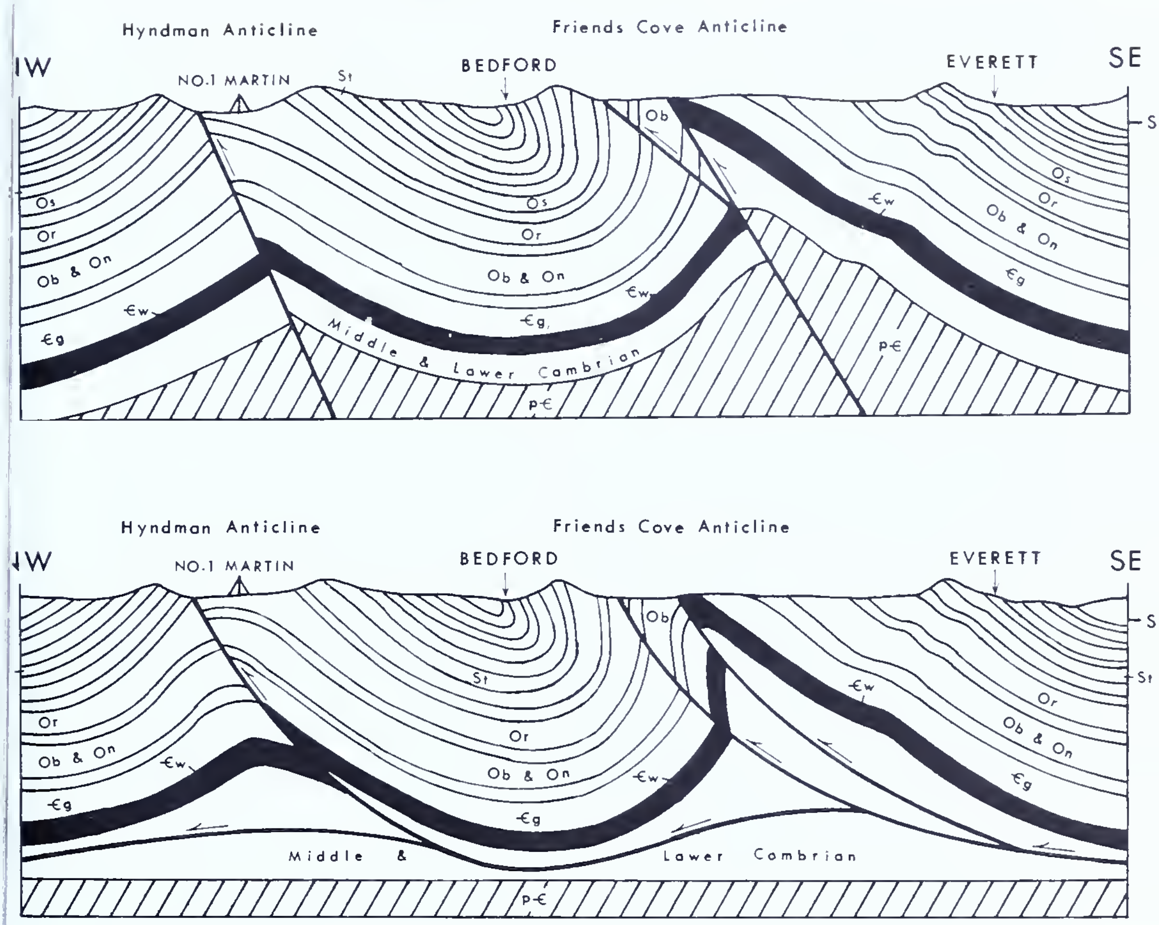
Thus, large displacement on a low angle overthrust fault could account for the formation of anticlines, which in turn could produce stresses that locally fold and fault the overlying strata in a manner similar to that found in the map area.

The cross section (Figure 16c) shows the inferred structure on the Nittany arch in south-central Pennsylvania. East of the area covered by the cross section is the Broad Top syncline, a large downfold containing rocks as young as Middle Pennsylvanian and representing an additional 10,000 feet of sediments beyond that shown in the cross section. West of the cross section is the Appalachian Plateau, underlain by beds of the same age as those found in the Broad Top syncline. In order to make room for this additional thickness of strata, it is necessary to hypothesize downfolds in the Precambrian basement to the east and west of the area of the cross section. The structural relief on the arched Precambrian basement would be on the order of 8,000 to 10,000 feet.

Rodgers (1949, 1953) has summarized the various arguments for and against basement involvement in the folds of the Ridge and Valley province. The hypotheses extend from the concept of the complete absence of basement involvement ("thin-skin hypothesis") to the idea that each anticline is the result of a high angle fault rising out of the basement ("thick-skin hypothesis").

Figure 17 shows geologic sections across the Hyndman and Friends Cove anticlines drawn according to "thick-skin" and "thin-skin" hypotheses. Both interpretations fit the outcrop pattern of the area. However, on the Hyndman anticline, neither interpretation can reconcile the surface outcrop pattern with the presence of a subsurface fault of large displacement. The record of the No. 1 Martin well indicates a subsurface fault of large enough displacement to put Lower Ordovician lower Beekmantown rocks in contact with the Upper Ordovician Reedsville Shale. An interpretation which would reconcile the surface outcrop pattern with the subsurface data from this well is shown in Figure 16c.

The conclusions presented previously in the report suggest that in south-central Pennsyvlania the basement appears to be broadly warped to correspond to the large regional structures such as the Allegheny Structural Front, the Nittany Arch, and the Broad Top syncline, but



b. Structural interpretation based upon "thin-skin" or nonbasement hypothesis. Compare with alternative "thin-skin" interpretation shown in Figure 16c. Symbols explained on Plate 1.

Figure 17. Geologic cross sections across Hyndman and Friends Cove anticlines illustrating "thick- and thin-skinned" interpretations of folds.

does not appear to be concordantly folded with the folds of the overlying Paleozoic rocks. The folds in the Paleozoic rocks can better be explained by the application of the mechanism of low angle overthrust faulting (Rich, 1934).

SUMMARY AND CONCLUSIONS

STRATIGRAPHIC AND PETROGRAPHIC STUDIES

The sedimentary rocks in the map area range in age from Upper Cambrian to Middle Devonian and have a total thickness of approximately 12,500 feet.

The sandy beds of the Warrior Formation include arkoses and orthoquartzites. Heavy mineral suites extracted from these sandstones indicate that the ultimate origin of the arkose and the orthoquartzite was a granitic-metamorphic terrane. Therefore, compositional differences between the sandstones probably reflect differences in topographic relief in the source area; that is, low relief for the orthoquartzite and higher relief for the arkose.

Pelto's cycles (1942) can be recognized in the Gatesburg Formation. However, greater understanding of the depositional history of the Gatesburg Formation is possible if the lithotypes are divided into two classes. The first class contains strata with primary structures and textures suggestive of deposition in quiet water, and the second class contains strata with primary structures and textures suggestive of deposition in more agitated water. If Pelto's cycles are examined in the light of these classes, the cycles are seen to consist of a combination of several inter-bedded sets of quiet and more agitated water lithotypes.

Petrographic studies of the occurrence of dolomite in the Warrior Formation, the Gatesburg Formation, the Benner, Hatter and Loysburg Formations, and the Tonoloway Formation indicate that the dolomite occurs as:

(1) A finely laminated, finely crystalline dolomitic rock;
(2) A coarsely crystalline, dolomitic rock containing ghosts of pellet or clastic grains;
(3) A dolomitic groundmass in which are imbedded calcareous pellets;
(4) Euhedral dolomite intimately associated with a calcilutite and
(5) A euhedral dolomitic groundmass in which are imbedded noncarbonate detrital grains.

Comparisons in thin sections of the primary sedimentary structures of the limestones and dolomites suggests that:

(1) Dolomitization took place after the sediment was deposited;
(2) The dolomitization process was favored by the increased permeability due to clastic grains;
(3) In general, in a carbonate rock the presence of clastic grains favors replacement and/or recrystallization; and
(4) There are some finely laminated, finely crystalline dolomites which may have formed by direct precipitation of dolomite.

Petrographic studies of oolitic chert from the Mines Dolomite indicate that the oolitic chert was the result of silification of calcareous oolites.

The Nittany Formation is a cyclic deposit. The complete, ideal cycle is composed of three phases: A finely laminated dolomite at the base, a structureless dolomite in the middle, and a mottled, often clastic dolomite at the top. The cycle probably reflects a subsidence below the zone of wave and current action together with sedimentary upbuilding to a level at which wave and current action being to rework the sediment, followed by subsidence and a new cycle.

The Keyser Formation is composed of nodular limestone in the lower part, banded arenaceous and cherty limestone in the middle, and finely laminated limestone in the upper part. Petrographic studies of the nodular limestones indicate that the nodules formed as a result of slippage and breakup of semi-consolidated layers and injection of a viscous, clastic-filled ooze between the broken fragments. The breakup and injection of the sediments may be due to deposition on an inclined surface or to the weight of the overlying sediment.

The Ridgeley Member of the Old Port Formation is composed of interbeded calcareous-, siliceous-, and ferruginous-cemented orthoquartzites. Petrographic data indicate that the ferruginous cement was introduced into the orthoquartzite at the time of or shortly after deposition.

STRUCTURAL STUDIES

The structural grain of the map area trends about North 20° East. The principal folds in the area are the asymetrical northward-plunging Friends Cove anticline, the southward-plunging Warrior Ridge anticline, and the doubly plunging Yellow Creek syncline.

The core of the Friends Cove anticline has been thrust westward onto its western flank by the Friends Cove fault. This fault cut out about 4000 feet of section. The Friends Cove fault is seen to pass into the right lateral transverse Everett Gap Fault. Field relations indicate that the transverse fault originated after reverse faulting on the Friends Cove fault began.

The East and West Henrietta faults are located west of the Warrior Ridge anticline. These faults bring a lens-shaped block of Upper Cambrian to Lower Ordovician strata into contact with Upper Ordovician strata. The writer has been unable to determine the steepness of dip on these faults and has therefore presented two working hypotheses to explain the map pattern. Depending upon the structural interpretation, the displacement on the faults is anywhere from one to two miles. The structural interpretations offered include high angle thrusting enclosing a large slice or a combination of low and high angle thrust faulting. Either of the hypotheses offered would fit into the map pattern.

The structural interpretation of the Friends Cove and the Hyndman anticlines (based partly on the well record from Kerr-McGee No. 1 Martin) suggests that the mechanism of low angle overthrust faulting postulated by Rich (1934) is applicable to the Ridge and Valley province. The Hyndman and Friends Cove anticlines are hypothesized to be the result of a westward displacement of about three miles of an allochtonous block above a major low angle thrust plane.

In south-central Pennsylvania, the Precambrian basement is suggested to be broadly warped to correspond to the large regional structures such as the Allegheny structural front, the Nittany arch, and the Broadtop syncline, but does not appear to be deformed concordantly with the folds of the overlying Paleozoic rocks.

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APPENDIX—DETAILED STRATIGRAPHIC DESCRIPTIONS OF SELECTED FORMATIONS OR MEMBERS

GATESBURG FORMATION

The Gatesburg Formation is exposed in road cuts along the Pennsylvania Turnpike, in Friends Cove, Snake Spring Valley, Everett quadrangle, Bedford County, Pennsylvania. The top of the Gatesburg crosses the Turnpike 2050 yards west of long. 78° 25′ W., and 1100 yards north of lat. 40° 00′ N. The upper portion is concealed so that the actual stratigraphic description begins 435 feet below the top. The section here exposed is:

Mines Dolomite
Gatesburg Formation
Upper sandy member

Unit		*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
	Concealed interval with typical weathered sandstone blocks. Measurement begins at farthest east block in place. 435 feet.		
1.	Dolomite, silty, medium-gray, laminated, buff-weathering, alternating one-foot-thick massive- and platy-bedded layers.	6	6
2.	Sandstone, medium-gray, fine sand, weathering buff with ribby surface, thin (up to 2 mm thick) medium-gray silt lenses aligned subparallel to bedding	1	7
3.	Dolomite, massive, dark-gray, fine-grained, buff-weathering.	1	8
4.	Covered interval, float suggests lithology similar to unit 1, with sandstone	4.5	12.5
5.	Dolomite, silty, platy to massive, similar to unit I.	4	16.5
6.	Dolomite, massive, dark-gray, medium-grained, weathers medium gray. Bedding, planar, spaced 8-12 inches. Two-foot-thick cross-bedded and laminated dolomitic sandstone in middle.	8	24.5
7.	Dolomite, platy weathering, dark-gray, fine-grained, weathers buff. Bedding, smooth, planar, spaced 2 to 4 inches.	2	26.5
8.	Sandstone, laminated, very fine sand, medium-gray, weathers buff. Bedding, smooth, planar, spaced 2 to 4 inches.	2	28.5
9.	Limestone, oolitic, fine-grained, dark-gray, weathers medium-gray with sandy texture.		

Unit		Unit Thickness (Feet)	Cumulative Thickness (Feet)
	Bedding, planar, rough-surface, spaced 2 inches.	2.5	31.0
10.	Dolomite, partially laminated, thick-bedded, fine-grained, dark-gray, weathers medium gray. Laminae 3 to 5 mm thick. Bedding, planar, rough-surfaced, spaced 12 inches.	3	34.0
11.	Dolomite, shaly, dark-gray, fine-grained, thin-bedded, weathers buff.	1.0	35.0
12.	Dolomite, partly laminated, thick-bedded, finely crystalline, medium-gray, weathers buff. Bedding, curving, spaced 1 to 2 feet.	3.0	38.0
13.	Limestone, with silty layers, partly bioclastic, platy, dark-gray, fine-grained, weathers yellowish-gray with ribby surface. Some silty layers show fine cryptozoon structure. Bedding, planar, rough-surfaced, spaced ¼ to ½ inch.	2.0	40.0
14.	Dolomite, massive, light-gray, fine-grained, weathers medium-gray. Bedding, curving, rough, spaced 10 to 12 inches.	4.0	44.0
15.	Sandstone and dolomite, lower half dolomite, dark-gray, finely crystalline, becomes sandy and grades into medium-gray, very fine-grained sandstone.	1	45.0
16.	Dolomite, silty, partly laminated, medium-grained, dark-gray, weathers medium-gray. Bedding, planar, rough, spaced 4 to 6 inches.	2	47.0
17.	Sandstone and arenaceous dolomite, interbedded, medium-light-gray, weathers buff, Gradational contacts between lithologies. Bedding, curving, rough-surfaced, spaced 10 to 12 inches.	2	49.0
18.	Dolomite, partly laminated, coarse-grained, medium-gray, weathers buff with ribby surfaces.	4	53.0
19.	Limestone, interbedded with thin wavy bands of silty limestone, fine-grained, dark-gray, weathers medium-gray. Bands ½ to 1 inch apart.	2.5	55.5
20.	Calcareous dolomite, laminated, medium-crystalline, dark-gray, weathers medium-gray. Laminae 1 to 5 mm thick. Bedding, smooth, planar, spaced 4 to 6 inches.	1	56.5
21.	Dolomite, partly laminated, dark-gray, fine-		

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
grained, weathers light-gray. Two-inch intraformational conglomerate at base.	1	57.5
22. Dolomite, massive, fine-grained, medium-gray, weathers light-gray. Bedding slightly curving, smooth, spaced 1 to 2 feet.	2.5	60.0
23. Limestone, oolitic, dark-gray, fine-grained, calcirudite, weathers medium-gray. One-inch intraformational conglomerate at base	0.5	60.5
24. Dolomite, faintly laminated, medium-gray, fine-grained, weathers light gray. Finely developed cryptozoon in lower half.	2.0	62.5
25. Limestone, massive, fine-grained, light-gray, weathers light-gray.	1.5	64.0
26. Dolomite, banded, fine-grained, medium-gray and light-medium-gray, weathers light-gray. Bands 1 inch thick.	20.	66.0
27. Limestone, massive, medium-grained, dark-gray, weathers medium-gray, middle portion partly laminated and cross-bedded. Bedding, smooth, slightly undulose, spaced 1 foot.	6.0	72.0
28. Limestone, intraformational conglomerate in part, interbedded with thin, wavy stringers of dolomite. Limestone, thin-bedded, medium-grained, dark-gray, weathers light-gray. Dolomite weathers yellowish-gray. Bedding spaced ½ to 1 inch.	2.0	74.0
29. Limestone, massive, dark-gray, fine-grained, weathers medium gray. One-foot-thick oolitic limestone and pebble conglomerate near top. Base marked by 1-foot-thick cryptozoon layer.	5.0	79.0
30. Dolomite, sandy, laminated and cross-bedded, dark-gray, medium-grained, weathers pinkish medium gray. Two-inch chert zone at top.	2.0	81.0
31. Sandstone, dolomitic, fine sand, medium-gray, weathers yellowish gray. Bedding, smooth, planar, spaced 12 to 16 inches.	2.5	83.5
32. Dolomite and sandstone, interbedded light-gray and buff-gray, fine-grained dolomite with buff-colored, fine-grained sandstone. Some thin sand stringers in dolomite. Bedding, planar, spaced 10 to 12 inches.	3.5	86.0
33. Dolomite, silty, laminated, thin-bedded.		

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
fine-grained, medium-gray, weathers buff with ribby surfaces. Top marked by thin quartzite stringers.	9.0	95.0
34. Limestone, massive, with black nodular cherts, fine-grained, black, weathers light gray. Cryptozoon layers in middle portion. Bedding, planar, smooth, spaced 10 to 12 inches.	5.0	100.0
35. Arenaceous dolomite, fine sand, medium-gray, weathers brownish gray with sand layers standing in relief. In part, thin sand layers trace cryptozoon structures. Bedding curving, rough, spaced 10 to 14 inches.	3.0	103.0
36. Sandstone and dolomite, medium-gray, crystalline dolomite at base grades up into buff-colored sandstone.	1.0	104.0
37. Dolomite, massive, fine-grained, dark-gray, weathers yellowish gray with ribby texture.	1.5	105.5
38. Dolomite, shaly, dark-gray, weathers yellowish gray.	0.5	106.0
39. Dolomite, calcareous, massive, fine-grained, dark-gray, weathers buff.	1.0	107.0
40. Limestone and calcareous dolomite, interbanded. Dark-gray, fine-grained bands of limestone separated by dark-gray bands of silty, cross-bedded, calcareous dolomite weathering yellowish gray. Bedding, smooth, planar, spaced 3 4 inches. weathers platy.	4.0	111.0
41. Limestone, massive, with sparsely distributed quartz silt. Calcilutite, dark-gray, weathers medium-gray. Some finely developed cryptozoon. Bedding, curving, rough-surfaced, spaced 10 to 12 inches.	4.2	115.2
42. Dolomite, cryptozoon, massive. Finely crystalline, light-gray, weathers whitish. Bedding, curving, rough-surfaced, spaced 1 foot. Top marked by 3-inch layer of black crystalline dolomite.	3.5	118.7
43. Limestone, massive, calcilutite, dark-gray, weathers light gray. Bedding, planar, rough-surfaced, spaced 10 to 12 inches.	5.5	124.2
44. Dolomite becoming sandy toward top with 6-inch sandstone layer on top. Dolomite, massive, fine-grained, medium-gray, weathers buff. Bedding, poorly developed, rough-		

Unit		*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
	surfaced, spaced 1 to 2 feet.	5.0	129.2
45.	Covered interval.	8.0	137.2
46.	Dolomite, laminated, fine-grained, light-gray, weathers whitish. Six-inch shaly dolomite layer at top. Bedding, planar, smooth, spaced 4 to 6 inches.	3.0	140.2
47.	Dolomite and sandstone, interbedded. Sandstones grade into dolomites. Dolomite, pinkish-medium-gray, weathers buff. Sandy dolomite portions weather to ribby surfaces. Bedding, planar, smooth, spaced 6 to 8 inches.	3.5	143.7
48.	Dolomite, oolitic. Some sand layers. Fine-grained, dark-gray, weathers medium-gray. Cross-bedded sandy layer at top. Bedding, curving, rough-surfaced, spaced 1 foot.	7.0	160.7
49.	Dolomite and sandy dolomite, interbedded. Fine-grained, light-gray and pinkish-gray dolomite, weathers whitish. Sandstone layer in middle.	2.5	153.2
50.	Mostly covered, but platy, silty-sandy beds.	4.0	157.2
51.	Dolomite, silty, partly laminated. Fine-grained, medium-gray, weathers buff with ribby surfaces. Bedding, planar, spaced 4 to 8 inches, becoming thicker bedded toward top.	4.5	161.7
52.	Limestone and silty dolomite, interbedded. Fine-grained, dark-gray limestone bands ½ to 1 inch thick separated by thinner nodular bands of silty dolomite. Limestone weathers light gray, dolomite, buff. Bedding, planar, rough-surfaced, spaced 4 to 8 inches.	7.0	167.7
53.	Limestone, massive (similar to 34 and 36), fine-grained, dark-gray, weathers light gray. One-foot-thick cryptozoon layer at top. Bedding, slightly curving, rough-surfaced, spaced 1 to 2 feet.		
54.	Dolomite, partly cryptozoon. Finely crystalline, dark-gray, weathers buff. Capped by one-inch-thick pink dolomite flat pebble conglomerate.	2.5	173.2
55.	Dolomite, massive, medium-crystalline, dark-gray, faintly laminated at base, weathers buff. Bedding, curving, rough-surfaced, spaced 1 to 2 feet.	3.5	176.7

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
56. Dolomite, massive, containing horn-shaped cherts and finely developed cryptozoon layers. Medium-grained, medium-gray, weathers light gray.	4.0	180.7
57. Orthoquartzite, containing some small rounded pebbles of buff-colored dolomite; very light-gray, weathers buff.	2.5	183.2
58. Dolomite and silty dolomite, interbedded and giving rock a banded aspect. Dolomite, massive, fine-grained, weathers yellowish gray or medium gray. Silty dolomite weathers with ribby surfaces. Bedding, planar, rough-surfaced, spaced 1 to 3 feet, mostly 3 feet.	11.0	194.2
59. Limestone, massive, fine-grained, dark-gray, weathers light gray.	0.5	194.7
60. Dolomite, mottled. Medium-crystalline, dark-gray, dolomite with medium-gray mottling, weathers light gray. Thin dolomitic flat pebble conglomerate in middle. Bedding, planar, rough-surfaced, spaced 1 to 2 feet.	3.5	198.2
61. Dolomite, laminated, very fine-grained, medium-gray, weathers yellowish gray. Laminae 1 to 2 mm.	0.5	198.7
62. Dolomite, massive, fine-grained, dark-gray, weathers yellowish gray with ribby surfaces. Bedding, planar, rough-surfaced, spaced 2 to 3 feet.	7.0	205.7
63. Domolitic limestone, massive, fine-grained, dark-gray.	2.0	207.7
Total well exposed upper sandy member of Gatesburg Formation		207.7 feet
Concealed portion at top of section		435.0 feet
Total upper sandy member of Gatesburg Formation		642.7 feet
Ore Hill Limestone Member		
64. Limestone, platy, fine-grained, very dark-gray, weathers medium gray, contains sparsely distributed quartz silt. Interbeds of thin wavy bands of silty limestone spaced 10 to 20 mm apart.	4.0	4.0
65. Dolomite, massive, fine-grained, dark-gray, weathers buff. Bedding smooth, slightly curving, spaced 1 foot.	2.0	6.0
66. Limestone, banded. One-inch-thick nodular		

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
bands of dark-gray aphanitic limestone separated by ¼-inch bands of silty dolomite, weathers light gray. Several one-inch-thick beds of flat pebble limestone conglomerate. Bedding, planar, rough-surfaced, spaced 1 to 2 feet, mostly 2 feet.	11.5	17.5
67. Conglomerate, limestone. Flat limestone pebbles and intraclastic matrix in a calcareous cement. Limestone, fine-grained, dark-gray, weathers light gray.	1.0	18.5
68. Limestone, banded. Similar to unit 66.	2.5	21.0
69. Dolomite, partly laminated and cross-bedded, medium - crystalline, dark - gray, weathers medium-gray. Some interbeds of oolitic dolomite. Bedding, planar, rough-surfaced, spaced 1 to 2 feet.	8.5	29.5
70. Dolomite, massive, with some laminated beds in middle part. Dolomite, finely crystalline, light-gray, grades up into 1½-foot-thick bed of very fine-grained, light-medium-gray limestone. Bedding, slightly curving, rough-surfaced, spaced to to 3 feet.	7.0	36.5
71. Mostly covered, top foot is thin bedded, silty dolomite and quartzite.	6.0	42.5
72. Dolomite, massive, medium-crystalline, very dark-gray, weathers brownish gray with sandy texture.	2.5	45.0
73. Poorly exposed, float suggests part of interval similar to unit 66. Thin-bedded limestone float with pink pebble conglomerate, flaggy limestone and cryptozoon.	10.0	55.0
74. Covered interval.	62.0	117.0
75. Dolomite, massive, medium - crystalline, medium-gray, weathers light gray.	5.0	122.0
76. Covered interval.	22.0	144.0
77. Limestone, aphanitic, dark-gray, weathering ribby and irregular.	3.0	147.0
Total exposed Ore Hill Limestone Member		147.0 feet
Lower sandy member		
78. Concealed interval.	335.0	335.0
79. Sandstone, dolomitic, fine sand, dark-gray, weathers medium gray.	1.0	336.0
80. Concealed interval, float contains buff-colored silty dolomite chips.	6.0	342.0

Unit	Unit Thickness (Feet)	Cumulative Thickness (Feet)
81. Sandstone, buff-colored, thin bedded at top, more massive and cross-bedded lower half. Weathers brownish-medium-gray. Bedding, smooth, planar, spaced 6 inches lower half, ½ inch upper half.	1.5	343.5
82. Concealed interval.	6.0	349.5
83. Sandy dolomite, fine-grained, thin-bedded, becoming thicker bedded toward base, dark-gray, platy. Bedding smooth curving, spaced ¼ to ½ inch upper half, 4 to 6 inches lower half.	2.0	351.5
84. Largely concealed, float contains light-medium-gray dolomitic sandstone, dark-gray oolitic dolomite, and thin-bedded, silty dolomite.	16.5	368.0
85. Dolomite, silty, thin-bedded, fine-grained, light-gray, weathering buff, and chippy.	1.0	369.0
86. Sandstone, partially cross-bedded and laminated. Fine-grained, medium-gray, weathers tannish medium gray, friable, with primary structures standing in relief. Bedding planar, lumpy, spaced 4 inches.	2.0	371.0
87. Sandy dolomite, cross-bedded, fine-grained, medium-gray, weathers dark gray with sandy textured surface. Bedding, smooth, slightly curving, spaced 4 to 8 inches.	1.0	372.0
88. Dolomite, silty, fine-grained, dark-gray, weathers to buff-colored chips.	0.5	372.5
89. Dolomite, oolitic, coarsely crystalline, dark-gray. Bedding, planar, rough-surfaced, spaced 1 foot.	2.0	374.5
90. Concealed interval, float largely sandstone.	15.0	389.5
91. Dolomite, largely oolitic, partly cross-bedded. Dark-gray, weathers medium gray with sandy texture. Bedding, curving, rough-surfaced, spaced 16 to 18 inches.	5.0	394.5
92. Concealed interval, some dark-gray, coarsely crystalline dolomite float with platy weathering medium-gray orthoquartzites at top.	46.0	440.5
93. Dolomite, oolitic, dark-gray, medium-crystalline, weathering brownish gray with ribby surfaces. Lower part consists of interbedded dark-gray, coarsely crystalline dolomite, sandstone and buff-weathering siltstone.	23.0	463.5

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
94. Buff silty dolomite, largely as float.	1.5	465.0
95. Concealed interval, float suggests interbedded oolitic chert, sandstone, and silty dolomite with some dark-gray coarsely crystalline dolomite.	52.0	517.0
96. Dolomite, oolitic, medium-crystalline, cross-bedded and massive, dark-gray, weathers medium-gray. Bedding poorly developed, spaced 1 foot.	4.0	521.0
97. Concealed interval.	6.0	527.0
98. Orthoquartzite, largely float.	1.0	528.0
99. Concealed interval.	4.0	532.0
100. Dolomite, medium-crystalline, dark-gray, weathers medium gray. Well - developed laminae and cross-bedding in some layers. Bedding smooth, curving, spaced 8 inches to 1 foot.	4.0	536.0
101. Concealed interval.	34.0	570.0
102. Partly concealed. Dolomite crystalline, dark-gray, weathers medium gray. Bedding. smooth, slightly curving, spaced 2 to 8 inches. Platy weathering. At top is sandy textured, buff-colored, platy dolomite with thin quartzite layers.	16.5	586.5
103. Concealed interval.	12.0	598.5
104. Thin- to medium-bedded, dark-gray, finely and medium-crystalline dolomite alternating with layers of arenaceous dolomite, partly cross-bedded, buff-weathering.	15.0	613.5
105. Basal orthoquartzite, cross-bedded, fine-grained, yellowish sandstone, weathers yellow brown. Bedding, rough, planar, spaced 1 foot.	3.0	616.5
Total thickness lower sandy member		616.5
Stacy Dolomite Member		
106. Dolomite, laminated, medium-gray, fine-grained, thin-bedded, weathers chippy with a tannish-light gray color.	4.0	4.0
107. Dolomite, massive, dark-gray and very dark-gray, medium to coarsely crystalline, weathers tannish medium gray. One-foot-thick cryptozoon layer in middle portion. Dark-gray, oolitic dolomite at top.	3.0	7.0
108. Dolomite, medium-gray, fine-grained, thin-		

Unit	Unit Thickness (Feet)	Cumulative Thickness (Feet)
bedded; similar to unit 1.	6.0	13.0
109. Dolomite, oolitic and pelletic, poorly exposed, dark-gray, coarsely crystalline, some cryptozoon beds.	9.0	22.0
110. Concealed interval.	4.0	26.0
111. Dolomite, oolitic, dark-gray, medium-bedded, medium-crystalline, weathers rust brown. Bedding, rough-surfaced, curving, spaced 1 foot	3.0	29.0
112. Concealed interval.	28.5	57.5
113. Dolomite, similar to unit 6.	3.0	60.5
114. Base concealed, contact based on float.	8.0	68.5
Total thickness Stacy Dolomite Member		68.5 feet
Total thickness Gatesburg Formation		1474.7 feet

LOWER MOHAWKIAN AND CHAZYAN STAGE LIMESTONES

In the New Enterprise quarry, south of Ashcom, Pennsylvania, excellent exposures of the lower Mohawkian and Chazyan stage rocks are to be found. The Stover and Snyder Members of the Benner Formation and the Hostler Member of the Hatter Formation are fully exposed in the south wall of the quarry. Of the Loysburg Formation, only the Clover Member and the top of the "tiger-striped" member are exposed. The section begins about 200 feet west of the southeast corner of the New Enterprise quarry about 1500 feet west of long. 78° 25′ W. and about 300 feet north of lat. 40° 00′ N., or about one-third mile south of Ashcom, Everett quadrangle, Bedford County, Pennsylvania. The section in descending order is:

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Nealmont Limestone		
Oak Hall Member		
1. Limestone, banded. Alternating ½- to 1-inch bands of dark-gray calcilutite and finely crystalline calcisiltite. Thin (1.0 mm), white lines of calcite mark contact between bands. Bedding, planar, rough, spaced 10 to 12 inches.	3.3	3.3
Measured thickness of Oak Hall Member		3.3 feet
Benner Formation		
Stover Member		
1. Limestone, massive, medium-bedded. Dark-gray calcilutite. Bedding, planar, rough, spaced 6 to 10 inches.	3.9	3.9
2. Limestone, faintly laminated, massive, thick-bedded. Medium-gray, very fine calcilutite containing unevenly distributed, thin (0.1 to 1.0 mm), dark-gray, bifurcating, crenulated laminae of silt separated by 1.0 mm to 2.0 cm thick layers of medium-gray calcilutite. Bedding, planar, rough-surfaced, spaced 12 to 16 inches.	15.1	19.0
3. Similar to Unit 21 but lacking lamination.	4.5	23.5
4. Limestone, banded, thick-bedded. One to two inches thick, slightly wavy bands of dark-gray calcilutite containing some crinoid plates as sparry calcite, alternating with ½- to 1-inch bands of darker gray, very slightly argillaceous, finely crystalline calcilutite. Bedding, smooth, slightly undulose, spaced 8 to 10 inches.	4.5	28.0
Total thickness of Stover Member		28.0 feet

Unit	*(Feet) Thickness Unit*	*(Feet) Thickness Cumulative*
Snyder Member		
5. Limestone, thick-bedded. Dark-gray, calcilutite layers containing a few crinoid plates as sparry calcite interbedded with 4- to 6-inch-thick layers of dark-gray, crystalline calcarenite similar to the unit below. Crystalline aspect due to recrystallized crinoid plates and shell fragments. Bedding, slightly curving, rough-surfaced, spaced 12 to 16 inches.	9.0	9.0
6. Limestone, thick-bedded. Dark-gray, crystalline calcarenite composed largely of crinoid plates, some bryozoan and shell fragments. Bedding, planar, rough-surfaced, spaced 10 to 14 inches.	4.3	13.3
7. Limestone, banded. Alternating ½- to 1-inch-thick wavy and discontinuous bands of dark-gray calcilutite containing large recrystallized biofragments, separated by dark-calcilutite bands poorer in biofragments. Bedding, planar, rough-surfaced, spaced 12 to 16 inches.	14.7	28.0
8. Limestone, massive, thick-bedded. Dark-gray calcilutite containing recrystallized bioclastic elements (bryozoan, crinoid plates, shell fragments) which impart a partly crystalline aspect. Darker gray, irregular, wavy stringers and clots of siltite. Bedding, planar, rough-surfaced, spaced 10 to 12 inches.	5.8	33.8
9. Limestone, massive, thick-bedded. Very dark-gray calcilutite. Bedding, planar, rough-surfaced, well-developed, spaced 12 to 16 inches.	12.0	45.8
10. Limestone, thick-bedded, banded. ½- to 1-inch-thick layers of dark-gray calcilutite containing small recrystallized biofragments, alternating with thin (¼ to ⅛ inch) wavy stringers of darker gray calcilutite poor in biofragments. Bedding, slightly curving, undulose surface, spaced 12 to 16 inches.	9.9	55.7
11. Limestone, massive, thick-bedded. Dark-gray calcilutite. Bedding, planar, smooth, spaced 10 to 14 inches.	3.0	58.7
Total thickness of Snyder Member		58.7 feet
Total thickness of Benner Formation		86.7 feet

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Hatter Formation		
Hostler Member		
1. Limestone, thick-bedded, banded. Dark-gray, slightly wavy, calcilutite layers ½ to 1 inch thick separated by darker gray, ¼- to ⅛-inch-thick layers. Both layers made up of unstructured ooze aggregates elongate parallel to bedding and giving thicker layers a mottled aspect. A few bioclastic elements. Some pyrite. Bedding, slightly curving, rough-surfaced, spaced 12 to 18 inches.	10.4	10.4
2. Offset, covered interval.	5.0	15.4
3. Limestone, dense, thick-bedded. Very dark-gray, very fine-grained calcilutite. Bedding, planar, lumpy-surfaced, spaced 16 to 18 inches.	6.0	21.4
4. Limestone, thick-bedded, banded. ¼- to ½-inch-thick, straight, even bands of very dark-gray, fine-grained calcilutite, separated by dark-gray, slightly silty, calcilutite layers of equal thickness. Bedding, planar, smooth-surfaced, spaced 10 to 14 inches.	11.9	33.3
5. Limestone, massive, thick-bedded. Very dark-gray, very fine calcilutite which breaks with conchoidal fracture. Bedding, planar, rough-surfaced, poorly developed, spaced 18 to 24 inches.	7.5	40.8
6. Limestone, massive, thick-bedded. Medium-gray calcilutite containing straight, even laminae, 1 to 3 mm thick, darker gray alternating with slightly silty dark-gray laminae of equal thickness. Bedding, planar, smooth, well-developed, spaced 8 inches.	11.9	52.7
7. Limestone, massive. Very fine calcilutite breaking with a conchoidal fracture. One-inch-thick, dark-gray, argillaceous limestone layer at top.	2.2	54.9
8. Limestone, medium - bedded, laminated. Dark-gray calcilutite containing 2 to 3 mm-thick slightly wavy, very dark-gray, laminae, separated by dark-gray laminae of equal thickness. Bedding, planar, rough-surfaced, spaced 8 to 12 inches.	5.9	60.8
Total thickness of Hostler Member		60.8 feet
Total thickness of Hatter Formation		60.8 feet

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Loysburg Formation Clover Member		
1. Limestone, dense, partly stylolitic. Medium-gray, very fine calcilutite breaking with a conchoidal fracture.	1.4	1.4
2. Limestone, thick-bedded, partly laminated. Dark-gray, very fine calcilutite showing faint lamination in middle portion. Bedding smooth, planar, spaced 12 to 14 inches.	4.3	5.7
3. Limestone, thick-bedded, partly laminated. Dark-gray calcilutite with some thin, straight, darker gray laminae, to give laminated aspect. Bedding, smooth, slightly curving, spaced 12 to 14 inches.	6.4	12.2
4. Limestone, massive, medium-bedded. Dark-gray, very fine calcilutite. Bedding, smooth, planar, spaced 8 inches.	1.2	13.4
5. Similar to Unit 40.	1.3	14.7
6. Similar to Unit 38.	1.3	16.0
7. Limestone, medium-bedded, partly laminated. 6- to 12-inch-thick layers of alternating massive and laminated, dark-gray calcilutite. Laminae are straight, even, 1 to 5 mm-thick bands of dark gray alternating with very dark gray. Bedding, smooth, planar, well-developed, spaced 6 to 12 inches.	11.8	27.7
Offset to north end of quarry to avoid present workings at south end.		
8. Limestone, massive. Medium-gray, finely crystalline calcilutite weathering light gray.	1.1	28.8
9. Limestone, dense, medium-bedded. Very fine-grained, calcilutite, breaking with a conchoidal fracture, and containing layers of sparsely distributed recrystallized biofragments. Bedding, well-developed, planar, spaced 6 to 8 inches. Weathers bluish medium gray.	8.3	37.1
10. Limestone, massive, medium-bedded. Dark-gray calcilutite weathering tannish gray. Bedding, smooth, planar, spaced 4 to 6 inches.	2.5	39.6
11. Dolomite, thin-bedded, laminated. Dark-gray dololutite, containing 2 to 3 mm thick, straight, even, alternating dark-gray and very dark-gray laminae, some of which are		

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
individually graded. Bedding, smooth, planar, spaced 2 inches.	1.1	40.7
12. Limestone, partly clastic and laminated. Dark-gray calcilutite containing some laminated layers and some thin 1- to 2-inch-thick layers of limestone conglomerate. Conglomerate consists of round to elliptically shaped calcilutite granules, 1 to 3 mm in diameter. Laminae 1 to 5 mm thick, straight, even bands, very dark-gray, and slightly silty, dark-gray, weathers light gray.	12.8	53.5
13. Limestone, massive, thick-bedded. Dark-gray calcilutite weathering tannish light gray. Bedding, planar, rough-surfaced, spaced 14 to 16 inches.	12.5	66.0
14. Concealed interval.	3.0	69.0
Total thickness Clover Member		69.0 feet
"Tiger-striped" Member		
15. Limestone, medium-bedded, banded. 1 to 2 cm thick, straight, slightly uneven bands of medium-gray, very fine calcilutite containing very small doubly terminated quartz crystals, alternating with equally thick bands of lighter medium-gray, slightly silty, very fine calcilutite. Weathers light gray. Bedding, planar, smooth, spaced 10 to 12 inches.	5.0	5.0
16. Dolomitic limestone, medium-bedded, partly laminated. Dark-gray dolocalcilutite interbedded with laminated layers. Laminated beds composed of 1 to 2 mm-thick, slightly wavy, alternating dark-gray and very dark-gray laminae. Some slump structures. Bedding, smooth, planar, spaced 6 to 10 inches. Weathers medium gray.	6.7	11.7
17. Limestone, thin-bedded, laminated. Dark-gray, laminated calcilutite composed of 1 to 2 mm-thick, slightly wavy, alternating dark-gray and very dark-gray laminae. Partly stylolitic. Bedding, planar, rough-surfaced, spaced 3 to 4 inches. Weathers tannish medium gray.	0.5	12.2
End of exposed section, west wall of quarry.		
Measured thickness of "Tiger-striped" Member		12.2 feet
Measured thickness of Lovsburg Formation		81.2 feet

NEALMONT FORMATION

In the New Enterprise limestone quarry south of Ashcom, the Coburn, Salona, and Nealmont Formations are fully exposed. Thompson (1961) has described the Coburn and Salona Formations in this quarry. The description which follows begins at the base of the Salona Formation and describes the three members of the Nealmont Formation. The section begins in the southeast corner of the quarry, about 1300 feet west of long. 78° 25′ W. and about 300 feet north of lat. 40° 00′ N., or about one-third mile south of Ashcom, Everett quadrangle, Bedford County, Pennsylvania. The section, in descending order, is:

Trenton Group
Salona Formation

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
1. Limestone with shaly partings. Dark-gray, dense, very fine-grained limestone with conchoidal fracture. Bedding planes, marked by ¼- to ½-inch-thick zones of shaly partings, spaced 6 inches. One-inch-thick, yellow-brown, weathering black, bentonite layer at base.	3.0	3.0
2. Limestone, thin-bedded, nodular. Dark-gray, dense, very fine-grained, nodular and banded limestone. 1- to 3-inch-thick layers separated by ½-inch-thick slightly shaly layers.	3.5	6.5
Measured thickness of Salona Formation		6.5 feet
Nealmont Formation Rodman Member		
1. Limestone, massive, partly crinoidal. Dark-gray, fine-grained limestone with crystallized crinoid plates. Bedding, planar, lumpy surfaced, poorly developed, spaced 8 to 12 inches.	7.0	7.0
2. Limestone, thin-bedded, shaly parting. Dark-gray calcilutite bands, 1 to 3 cm thick, containing a small amount of biofragmental material, imparting crystalline aspect. Alternating with 1 to 5 mm-thick silt and calcilutite layers. Bedding, rough-surfaced, bifurcating, spaced 1 to 2 inches.	4.3	11.3
3. Limestone, massive, thick-bedded. Dark-gray calcilutite containing many fine crystals of calcite, probably crinoid plates. Some small (0.1 mm) pyrite crystals.	4.2	15.5

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
4. Limestone, shaly parting, thin-bedded. Dark-gray calcilutite in 1- to 2-inch-thick layers separated by ⅛- to ¼-inch carbonaceous agrillaceous partings. Bedding, poorly developed, spaced 6 to 8 inches.	4.5	20.0
5. Limestone, massive, thick-bedded. Dark-gray calcilutite with scattered biofragmental elements, mostly crinoid plates giving rock a partly crystalline aspect. Bedding, planar, slightly undulose, well-developed, spaced 2 to 3 feet.	17.2	37.2
6. Limestone, shaly parting, thin-bedded. 1- to 3-inch layers of dark-gray calcilutite with scattered biofragments, trilobite fragments, crinoid plates. Crinoid plates give rock partly crystalline aspect. Bedding marked by ⅛ to ¼ inch thick layers of carbonaceous, argillaceous limestone.	1.5	38.7
Total thickness Rodman Member		38.7 feet
Centre Hall Member		
7. Limestone, massive, thick-bedded. Dark-gray calcilutite with crinoid plates as sparry calcite giving rock partly crystalline aspect. Many poorly preserved ostracode tests. Some pyrite. Bedding, lumpy surface, slightly curving, spaced 10 to 12 inches.	3.0	3.0
8. Limestone, shaly parting, thin-bedded. Dark-gray calcilutite similar to unit 8, but containing fewer crinoid plates. Bedding marked by ¼- to ½-inch-thick carbonaceous argillaceous layers.	2.2	5.2
9. Limestone, massive, thick-bedded. Dark-gray calcilutite, bedding, smooth, planar, spaced 12 to 18 inches. About 18 inches above base is 6-inch-thick layer of thin-bedded argillaceous limestones.	6.6	11.8
10. Limestone, partly laminated. Unit consists of alternating laminated and nonlaminated layers, becoming mostly laminated in lower 36 inches. Laminae are slightly wavy, 1 to 2 mm thick, dark-gray calcisiltite bands separated by medium-gray calcilutite bands. Bedding, smooth, planar, spaced 6 to 10 inches in upper part, 4 to 6 inches in lower 36 inches.	8.2	20.0

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
11. Limestone, massive, thick - bedded, partly laminated. Medium-gray, very fine calcilutite similar to Unit 12. Laminated porlutite similar to Unit 12. Laminated portion, very-thin (0.1 mm), curving, crenulated, dark-gray subparallel lines, separated by 5 to 10 mm-thick layers of medium-gray calcilutite. Bedding planar, smooth, well-developed, spaced 10 to 16 inches.	2.2	28.2
12. Limestone, medium-bedded, partly laminated. Dark-gray calcilutite containing 6-inch-thick laminated layer 6 inches above base. Laminae thin (0.1 to 1.0 mm), wavy crenulated, bifurcating, very dark-gray, subparallel siltite layers separated by 1 to 5 mm dark-gray calcilutite layers. Bedding, smooth, slightly curving, spaced 10 to 12 inches.	2.9	31.1
Total thickness Centre Hall Member		31.1 feet
Oak Hall Member		
13. Inaccessible and partly concealed, offset to next ledge.	10.0	10.0
14. Limestone, medium-bedded, partly crinoidal. Dark-gray calcilutite containing many crinoid plates as sparry calcite which give rock a crystalline aspect. Bedding, planar, rough-surfaced, spaced 8 to 12 inches. Weathers light gray.	5.8	15.8
15. Limestone, dense, medium-bedded. Dark gray, very fine-grained calcilutite with crinoid plates as sparry calcite, and worm-like tubes filled with sparry calcite, which together impart a partly crystalline aspect to the rock. Some poorly preserved ostrocods. A few thin (1 to 3 mm), wavy, irregular stringers, of finely crystalline calcisiltite. Bedding, planar, spaced 12 to 16 inches.	3.9	19.7
16. Limestone, dense, thick-bedded. Dark-gray, very fine calcilutite. Bedding, planar, rough-surfaced, spaced 14 to 18 inches.	3.3	23.0
17. Limestone, banded. Alternating ½- to 1-inch bands of dark-gray calcilutite and finely crystalline calcisiltite. Thin (1.0 mm) white lines of calcite mark contact between bands. Bedding, planar, rough, spaced 10 to 12 inches.	3.3	26.3
Total thickness of Oak Hall Member		26.3 feet
Total thickness of Nealmont Formation		86.1 feet

BLOOMSBURG FORMATION

Two sections were measured to illustrate the lateral variation in color that occurs in the Bloomsburg Formation. The first section is located in a road cut on the south side of the county road northeast of Loysburg Gap and about ½ mile north of Route 868, or 4400 feet west of long. 78° 20′ W. and 300 feet south of lat. 40° 10′ N.

Wills Creek Formation

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Mudstone, medium-gray, calcareous, weathering light medium gray. Bedding, poorly developed, spaced 1 to 3 inches.	10	10
Transition zone. One- to three-foot-thick layers of alternating greenish-gray and reddish-gray, calcareous shale and mudstone.	20	20
Measured Wills Creek Formation		30 feet
Bloomsburg Formation		
1. Upper shale. Grayish-red, noncalcareous mudstone. Bedding, rough-surfaced, spaced about 24 inches.	15	15
2. Upper sandstone. Grayish-red, very fine-grained sandstone. Bedding 18 to 20 inches.	6.7	21.7
3. Middle shale. Partly concealed. Grayish-red shale and mudstone upper ⅔, dusky-yellow-green shales and mudstone lower ⅓. Mud cracks on bedding planes of grayish-red shale. Near base shale is limonite-stained, weathers punky.	11.0	32.7
4. Lower standstone. Grayish-red, very fine-grained sandstone. Bedding, rough-surfaced, spaced 8 to 12 inches. Eight-inch, dusky-yellow-green sandstone at top.	8.1	40.8
Total thickness Bloomsburg Formation		40.8 feet
Mifflintown Formation		
Medium-olive-gray noncalcareous mudstone. Bedding, smooth, planar, spaced 1 inch.	2.0	

The second section is located along the strike of the first, approximately 2 miles south, on a farm road cut through the Bloomsburg ridge about 1½ miles south of Loysburg Gap and 1½ miles west-northwest of Yellow Creek, or 6700 feet west of long. 78° 20′ W. and 10,650 feet lat. 40° 10′ N. The section is given in descending order.

Wills Creek Formation

Transition zone, concealed.

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Bloomsburg Formation		
1. Upper shale. Partly concealed. Grayish-red mudstone and shale.	16.0	16.0
2. Upper sandstone. Thick-bedded, grayish-red, very fine-grained sandstone. Bedding 2 feet. Lower 18 inches, dusky-yellow-green, fine-grained sandstone with 1-inch transition zone at top.	9.5	25.5
3. Middle shale. Top 2 feet, grayish-red shale; middle portion, dusky-yellow-green shale and mudstone. At base, 3-foot-thick layer of limonite-stained shales.	13.0	38.5
4. Lower sandstone. Upper 42 inches, dusky-yellow-green, very fine-grained, calcareous, limonite-stained. Bedding, rough-surfaced, spaced 4 to 6 inches. Lower portion, grayish-red, medium-bedded, very fine-grained sandstone. Bedding, rough-surfaced, spaced 8 to 12 inches.	10.9	49.4
Total thickness of Bloomsburg Formation		49.4 feet

Mifflintown Formation concealed.

OLD PORT AND KEYSER FORMATIONS

The Keyser Formation and the lower part of the Old Port Formations are partially exposed at Everett, on U.S. Route 30 in the old quarry opposite the steel vehicular bridge across the Raystown Branch, or 3100 feet north of lat. 40° 00′ N. and 10,400 feet east of long. 78° 25′ W. Float similar to the lumpy limestones of the basal portion of the Keyser Formation is found 50 feet to the west of the lowest exposure suggesting that not all of the basal Keyser is exposed. Most of the same strata also may be seen in an old quarry located 2000 feet south of the quarry at Everett. It is 800 feet north of lat. 40° 00′ N. and 9500 feet east of long. 78° 25′ W. The section in descending order is:

Old Port Formation

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
1. Limestone, somewhat lumpy. Medium-dark-gray, fine-grained, weathers yellowish gray and earthy.	7	7
2. Limestone, argillaceous, medium-dark-gray, fine-grained, coral fragments and crinoid stems scattered throughout. Bedding rough-surfaced, undulose, spaced 30 inches. Weathers tannish gray.	6.9	13.9
3. Limestone, argillaceous, medium - bedded, medium-dark-gray, fine-grained, containing small whitish recrystallized biofragments. Silicified specimens of *Atrypa reticularis* and *Gypidula coeymanensis* occur. Chert nodules present.	9.0	22.9
Total Old Port Formation exposed		22.9
Keyser Formation		
1. Interbedded sequence. Medium-dark-gray, silt-laminated, thin-bedded limestone interbedded with lumpy limestone composed of silt, laminated, medium-gray-dark, ooze aggregates separated by thin, orange-gray silty zones. Bedding, spaced 8 to 12 inches. 2-foot-thick fossiliferous horizons located 1 foot from top and 8 feet above base.	19.7	19.7
2. Limestone, thick-bedded, medium-dark-gray, fine-grained. Weathers medium light gray. Bedding, poorly developed, surface rough, undulose, spaced 3 to 4 feet.	9.9	29.6
3. Limestone, biofragmental and argillaceous, dark-gray, fine-grained, with many biofrag-		

Unit		*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
	ments. Bedding, planar, lumpy surfaces, spaced 8 to 12 inches. Cherty zone 3 feet from top.	6.0	35.6
4.	Limestone, partially biofragmental, finely crystalline, dark-gray, containing recrystallized crinoid plates. Lower 5 feet crinoid plates abundant. Numerous dark-gray chert nodules and stringers in middle portion. Bedding rough surfaced, planer, spaced 3 to 4 feet.	11.8	47.4
5.	Limestone, massive, dark-gray, fine-grained, containing small yellowish-orange specks. Several 1- to 2-foot-thick algal limestone layers. Some black chert stringer. Bedding, poorly developed, spaced 2 feet.	18.0	65.4
6.	Limestone, massive, medium-bedded, dark-gray, fine-grained, partly laminated, containing small yellowish-orange specks. Some dark-gray chert nodules and stringers. Bedding, well-developed, spaced 10 to 12 inches.	24.0	89.4
7.	Limestone, laminated, dark-gray, fine-grained, thin-bedded, weathering medium light gray. Bedding, well-developed, spaced ¼ to ½ inch.	2.0	91.4
8.	Limestone, fine-grained, dark-gray, finely laminated, weathers light olive gray.	1.3	92.7
9.	Limestone, laminated, dark-gray, finely laminated, weathers light olive gray.	0.9	93.6
10.	Limestone, arenaceous, partially laminated, thick-bedded, dark-gray, finely crystalline, weathers medium brownish gray. Laminated layers interbedded with cross-laminated and nonlaminated layers. 4- to 5-inch-thick, light-gray and medium-gray chert nodules in lower 5 feet. In some cases, laminations can be traced through cherts. Bedding, rough, undulose, spaced 2 to 3 feet.	15.5	109.1
11.	Limestone, laminated, thin-bedded, finely crystalline, medium-gray. Several 1-inch-thick chert stringers. Fossiliferous including numerous stromatoporoids.	4.0	113.1
12.	Limestone, banded, slightly lumpy. 2- to 3-inch-thick slightly lumpy bands of dark-gray, finely crystalline limestone, separated by very thin, argillaceous limestone layers. Interbedded with thin layers of medium-		

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
crystalline, dark-gray limestone containing whitish recrystallized biofragments. Weathers medium light gray. Bedding, rough-surfaced, planar, poorly developed, 12 to 16 inches, pronounced at 4-foot intervals.	71.0	184.1
13. Limestone, laminated, dark-gray, fine-grained, weathers tannish gray. Laminae 2 to 3 mm thick. Bedding, planar, smooth, spaced 5 to 8 inches. Some chert stringer near base.	14.0	198.1
Ttotal exposed Keyser Formation		198.1
14. Concealed interval. Float and poor exposure on the hill slope west of the quarry suggests that perhaps some of the basal Keyser is not exposed. The lithology of Unit 13, however, is identical to the Tonoloway Formation; thus, the covered interval may represent an interbedded zone of two lithologies.		

RIDGELEY SANDSTONE MEMBER OF THE OLD PORT FORMATION

The Ridgeley Sandstone Member is fully exposed in the cut for the Pennsylvania Turnpike at Everett, Bedford County, Pennsylvania. The section begins at the east end of the cut, or 1750 feet north of lat. 40° 00′ N. and 1000 feet east of long. 78° 23′ N. The section here is:

Onondaga Formation

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Dark-gray noncalcarous shales, weathers medium gray.		
Old Port Formation		
Ridgeley Sandstone Member		
1. Sandstone, dark-gray, medium-grained, cross-bedded and laminated, orthoquartzite, weathers dark yellowish orange. Very coarse sand at base. Bedding, irregular, spaced 6 to 12 inches.	36.0	36.0
2. Sandstone, light-gray, medium-grained, siliceous orthoquartzite. Bedding, rough-surfaced, planar, well-developed, spaced 1 to 4 inches.	6.0	42.0
3. Sandstone, tannish, medium-grained, siliceous orthoquartzite.	1.0	43.0
4. Sandstone, tannish, medium-grained, siliceous orthoquartzite. Bedding, poorly developed, spaced 3 to 6 inches.	6.0	49.0
5. Sandstone, dark-gray, very coarse grained orthoquartzite with a siliceous and hematitic cement.	0.5	49.5
6. Sandstone, whitish, medium-grained, orthoquartzite, cross-bedded, low dips (10° to 15°). Bedding, well-developed, planar, spaced 2 to 6 inches.	4.0	53.0
7. Sandstone, dark-gray, laminated and cross-bedded, medium-grained, siliceous orthoquartzite, weathers reddish brown. Bedding, rough-surfaced, poorly developed, spaced 2 to 6 inches.	6.0	59.0
8. Sandstone, whitish, medium-grained, siliceous orthoquartzite, weathers brownish. Bedding, poorly developed, spaced to 2 to 6 inches.	5.0	64.0
9. Sandstone, dark-gray, fine-grained, orthoquartzite; poorly bedded.	3.0	67.5

Unit	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
10. Sandstone, whitish to tannish, medium-grained, siliceous orthoquartzite. Bedding, poorly developed, curving, spaced 1 to 2 feet.	36.5	104.0
11. Sandstone, light-tannish, friable, orthoquartzite. Bedding, spaced 12 to 18 inches, rough-surfaced, undulose, well-developed.	7.0	111.0
Total thickness Ridgeley Sandstone Member		111.0 feet

ONONDAGA FORMATION

About one mile north of Eichelbergtown, Everett quadrangle, Bedford County, Pennsylvania, the Onondaga Formation is fully exposed along an old farm road on the north side of the creek that cuts through the Ridgeley sandstone ridge at this point. The section is located about 3200 feet south of lat. 40° 10′ N. and about 10,200 feet east of long. 78° 20′ W. The section is as follows:

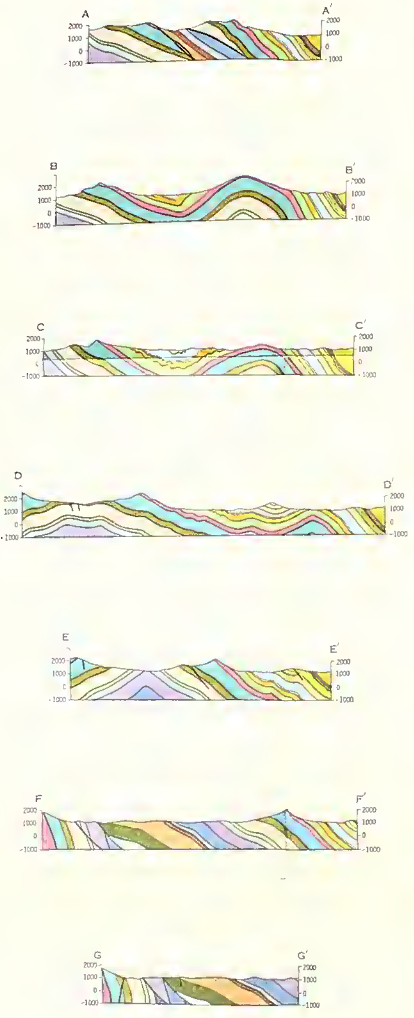
Marcellus Formation *Unit*	*Unit Thickness (Feet)*	*Cumulative Thickness (Feet)*
Black noncalcareous shale, fragments weather grayish black with a whitish edge.		
Onondaga Formation		
1. Concealed interval.	10.0	10.0
2. Limestone, argillaceous. Thin-bedded, dark-gray, weathers greenish gray.	20.0	30.0
3. Limestone, dark-gray, fine-grained, weathers tannish	0.5	30.5
4. Shale, calcareous, dark-gray, thin-bedded, weathers greenish gray.	14.0	44.5
5. Limestone, dark-gray, fine-grained, weathers pale olive.	0.5	45.0
6. Shale, calcareous, thin-bedded, greenish-gray, weathers tannish.	10.3	55.3
7. Shale, calcareous, thin-bedded, dark-gray, weathers brownish gray.	2.8	58.1
8. Shale, calcareous, thin-bedded, greenish-gray, weathers pale olive.	3.3	61.4
9. Mudstone, calcareous, dark-gray, weathers tannish.	0.2	61.6
10. Shale, calcareous, thin-bedded, dark-gray, weathers medium gray.	3.0	64.6
11. Similar to above but noncalcareous.	7.0	71.6
12. Shale, thin-bedded, greenish-gray, weathers yellow brown.	2.0	73.6
13. Concealed interval, float indicates dark-gray, noncalcareous shale.	2.0	75.6
14. Concealed interval, float indicates dark-brownish-gray, noncalcareous shale, weathers yellowish green.	2.0	77.6
Total thickness Onondaga Formation		77.6 feet
Ridgeley Sandstone Member		
Orthoquartzite, whitish, medium-grained.		

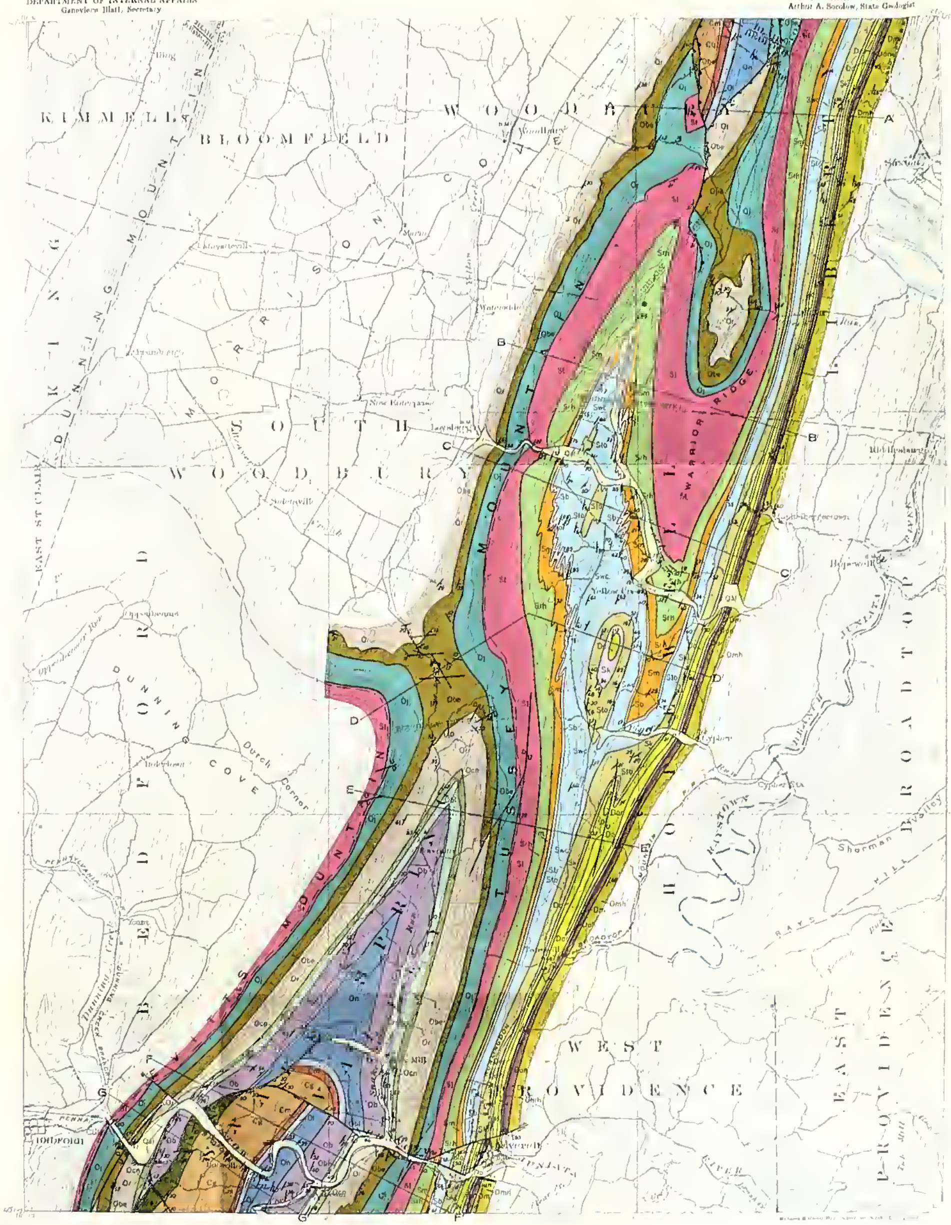
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

PROGRESS REPORT 170, PLATE 1

GEOLOGIC CROSS SECTIONS





Base from U.S. Geological Survey, 15′ series, topographic map of the Everett quadrangle, Pennsylvania, 1962

Geology by R. R. Knowles, 1961-1963
(Slightly modified by D. M. Hoskins, 1965)

EXPLANATION

QUATERNARY
Recent

Qal
Recent Stream Deposits
Unconsolidated floodplain deposits sufficiently thick to completely conceal bedrock.

DEVONIAN
Middle Devonian

Dmh
Mahantango Formation
Interbedded dark- and olive-gray shale and siltstone. Middle part with 25 to 40 feet of dark-gray, fine-grained sandstone.

Dm
Marcellus Formation
Black fissile shale.

Lower or Middle Devonian

Don
Onondaga Formation
Interbedded gray calcareous and noncalcareous shale. Near the top are a few thin interbeds of dark-gray argillaceous limestone.

Lower Devonian

Dor
Do
Old Port Formation
Light-gray, fine- to very coarse-grained, thick-bedded orthoquartzite at top—Ridgeley Member (Dor). Dark-gray siliceous shale and siltstone in middle and dark-gray, medium-bedded limestone, locally with biohermal masses and chert at base—Shriver, "New Scotland" and "Coeymans" Members (Do).

SILURIAN
Upper Silurian

Sk
Keyser Formation
Dark-gray laminated limestone in upper part, arenaceous and cherty near middle, light- to dark-gray, fine to coarsely crystalline, nodular limestone in lower part.

Sto
Tonoloway Formation
Medium- to dark-gray laminated limestone and argillaceous limestone.

Swc
Wills Creek Formation
Interbedded dark-, olive- and greenish-gray, calcareous and noncalcareous shale and argillaceous limestone. A few interbeds of grayish-red shale and gray, fine-grained sandstone.

Middle Silurian

Sb
Bloomsburg Formation
Interbedded grayish-red and gray shales. Two persistent 6- to 8-foot grayish-red siltstone units near middle.

Lower Silurian

Sm
Mifflintown Formation
Olive- and greenish-gray shale with interbeds of dark-gray shale and limestone. Grayish-red shale 90 feet thick in upper one-third (Rabbit Run Member). Basal 5-10 feet light- to dark-gray, calcareous and ferruginous sandstone with some beds of hematitic limestone (Keefer Member).

Sr
Rose Hill Formation
Interbedded olive-, greenish-, brownish- and reddish-gray shale and siltstone. A few interbeds of grayish-red, fine- to medium-grained, ferruginous sandstone.

St
Tuscarora Formation
Light-gray and tannish, laminated and cross-bedded, thick-bedded, siliceous orthoquartzite.

ORDOVICIAN
Upper Ordovician

Oj
Juniata Formation
Interbedded reddish-gray, fine- to coarse-grained sandstone, siltstone and shale. Sandstones predominant near base and top, shales in middle.

Obe
Bald Eagle Formation
Brownish- to greenish-gray, fine- to coarse-grained, laminated and cross-bedded, medium- to thick-bedded sandstone with some shale. Grayish-red beds near middle.

Or
Reedsville Formation
Olive-, greenish- and [illegible]-gray shale and siltstone. Prominent [illegible]

Middle Ordovician

Ocn
Coburn, Salona and Nealmont Formations undivided
Dark-gray, laminated and cross-bedded limestone (Coburn); dark-gray, argillaceous limestone with some metabentonites (Salona); dark-gray, laminated and crinoidal limestone (Nealmont).

Obl
Benner, Hatter and Loysburg Formations undivided
Medium-gray, massive and crinoidal limestone (Benner); dark-gray, massive and banded limestone (Hatter); interbedded laminated and banded limestone with dolomite interbedded near the base (Loysburg).

Lower Ordovician

Ob
Bellefonte Formation
Light- to dark-gray, medium- to thick-bedded, partially laminated dolomite. Chert abundant in lower half.

On
Nittany Formation
Dark- to medium-gray, medium- to thick-bedded, partially laminated, mottled dolomite. White oolitic cherts common.

Ol
Larke Formation
Medium- to dark-gray, laminated, oolitic and calcareous dolomite.

CAMBRIAN
Upper Cambrian

Cm
Mines Formation
Medium- to dark-gray, crystalline dolomite and abundant oolitic chert.

Cg
Gatesburg Formation
Interbedded medium- to dark-gray, laminated dolomite and sandstone. Interbedded limestone and dolomite (Ore Hill Member) near middle. Cherty crystalline dolomite with algal [illegible] (Stacy Member) at base.

Cw
Warrior Formation
Medium- to dark-gray, mottled and [illegible] dolomitic sandstone near the middle.

SYMBOLS

Geologic contact, accuracy not defined.

Strike and dip of beds

Strike and dip of overturned beds

Horizontal beds

D
U
High angle (45° to 90°) fault, dashed where probable. U - upthrown side, D - downthrown side. Arrows indicate relative movement on transverse faults.

Low angle (0° to 45°) reverse fault. Saw teeth on upper plate indicate direction of dip.

A——A′
Line of geologic cross-section.

GEOLOGIC MAP OF A PORTION OF THE EVERETT QUADRANGLE, PENNSYLVANIA

SCALE 1:24000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

1966